ER BERG RURAL ECONOMY LIBRARY
21386

Digitized by the Internet Archive
in 2017 with funding from
University of Alberta Libraries

https://archive.org/details/odupong1999

E. R. BERG MEMORIAL LIBRARY
Department of Rural Economy
University of Alberta
Edmonton, Alberta T6G 2H1
Phone (403) 432-4225

University of Alberta

Library Release form

NAME OF AUTHOR: Ernest Abbey Odupong

TITLE OF PAPER: A Model Framework For BST Impact Assessment On The Alberta Dairy Industry

DEGREE: Master of Agriculture

YEAR THIS DEGREE WAS GRANTED: 1999

Permission is hereby granted to the University of Alberta Library to reproduce single copies of this paper, and to lend or sell such copies for private, scholarly, or scientific research purposes only.

The author reserves other publication rights, and neither the paper nor any substantial portion from it may be printed or otherwise reproduced in any material form whatever without the author's prior written permission.

....

Ernest Abbey Odupong
Post Office Box 11
Ekumfi Ekrawfo
Via Saltpond
Ghana

Date: APRIL 4, 1999

THE UNIVERSITY OF ALBERTA

A MODEL FRAMEWORK FOR BST IMPACT ASSESSMENT ON THE ALBERTA DAIRY INDUSTRY

by

Ernest Abbey Odupong

A PROJECT
SUBMITTED TO THE DEPARTMENT OF RURAL ECONOMY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF AGRICULTURE
IN
AGRICULTURAL ECONOMICS

DEPARTMENT OF RURAL ECONOMY
EDMONTON, ALBERTA

SPRING, 1999

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommended to the Department of Rural Economy, for the acceptance, a paper entitled **A MODEL FRAMEWORK FOR BST IMPACT ASSESSMENT ON THE ALBERTA DAIRY INDUSTRY** submitted by Ernest Abbey Odupong in partial fulfilment of the requirements for the degree of Master of Agriculture in Agricultural Economics.

....

Supervisor

T.T. Veeman..

GW Mathison..

Date 23rd March, 1999

DEDICATION

To my beloved mother, Sarah Aba Hayford whose love and encouragement are being kept in my memory forever.

ABSTRACT

The objective of this study is to develop a model framework that could be used to assess the impact of BST in the Alberta dairy sector. The paper provides a review of BST in terms of the effects on dairy cows, milk production, feed requirements, health and longevity, and reproductive capacity. It also makes mention of possible farm-level adoption scenarios. The paper provides a review of the economic literature related to BST, highlights some of the studies done on BST and the methodology used and results obtained from the studies.

The paper also identifies and discusses an appropriate theoretical model that can be used to explain the economics of BST adoption. An empirical model appropriate for farm-level and sector-level is identified and discussed in the paper. An empirical analysis of BST adoption for a representative farm, using partial budgeting and break even analysis, is identified and discussed. The empirical results from the partial budgeting suggest that producers would benefit most by adopting BST on all the available cows and acquiring extra quota to support the increased milk production. Generally, BST may have the potential of increasing milk producer's net returns but this will depend on factors like herd size, region of location, quota level, quota value, milk prices, BST cost and the costs of other inputs. Finally, the questions that need to be addressed to enable this framework to be carried out were identified and discussed.

ACKNOWLEDGEMENT

I would first of all, like to express my gratitude to the Almighty God for his grace, guidance and blessings that enabled me to complete this project. I am very grateful to my supervisor Dr. Scott Jeffrey for his advice, support and relentless editing of the drafts throughout the entire course of this project. I would also like to express my gratitude to members of my project committee Dr. Terry Veeman (committee chairman) and Dr. Gary Mathison for their insightful comments. Special thanks goes to Dr. Michele Veeman for her support throughout my studies. To all the professors whom I happened to take courses with, I say thank you.

Thanks to the academic and administrative staff of Rural Economy Department for their direct and indirect contribution and support throughout my studies at department. And finally, I would like to thank all my friends and colleagues who directly or indirectly contributed towards the completion of this project.

TABLE OF CONTENTS

SECTION 1 - INTRODUCTION 1

1.1 BRIEF BACKGROUND 1

1.2 STATEMENT OF ECONOMIC PROBLEM 2

1.3 OBJECTIVES 3

1.4 REPORT OUTLINE 3

SECTION 2 - BOVINE SOMATOTROPIN (BST) 5

2.1 WHAT IS BST? 5

2.2 HOW BST WORKS 6

2.3 BST EFFECTS ON MILK PRODUCTION 8

2.4 BST EFFECTS ON FEED REQUIREMENTS 10

2.5 BST EFFECTS ON COWS' HEALTH 13

2.6 BST EFFECTS ON REPRODUCTIVE CAPACITY 13

2.7 ADOPTION SCENARIOS 15

SECTION 3 - LITERATURE REVIEW 17

SECTION 4 - THEORETICAL MODEL 22

4.1 PRODUCTION ECONOMICS THEORY 22

4.2 LINEAR PROGRAMMING MODELS 25

4.3 RATIONALE FOR USING LINEAR PROGRAMMING 27

SECTION 5 - EMPIRICAL MODEL 29

5.1 EMPIRICAL MODEL APPROACH 29

5.2 REPRESENTATIVE FARMS 30

5.3 GENERAL MODEL STRUCTURE 30
5.3.1 OBJECTIVE FUNCTION 31
5.3.2 DAIRY BLOCK 32
5.3.3 CROP BLOCK 33
5.3.4 FARM BLOCK 33
5.3.5 DATA FOR THE LP MODEL 34
5.4 INTRODUCTION OF BST INTO THE MODEL 35
5.5 A LINEAR PROGRAMMING MODEL CONSTRUCTION FOR A REPRESENTATIVE FARM 36
5.6 MODEL PROCEDURE 42
5.7 SENSITIVITY ANALYSIS 43
5.8 OTHER ISSUES 43
SECTION 6 - INITIAL EMPIRICAL ANALYSIS 44
6.1 INTRODUCTION 44
6.2 EMPIRICAL ANALYSIS 44
6.3 REPRESENTATIVE FARM 45
6.4 IMPACTS OF BST 50
6.5 BST ADOPTION SCENARIOS 53
6.5.1 HERD SIZE REDUCTION SCENARIO 53
6.5.2 QUOTA EXPANSION SCENARIO 54
6.6 BST IMPACTS AND PARTIAL BUDGETS 55
6.7 BREAK EVEN ANALYSIS 57
6.8 CONCLUDING COMMENTS 59

SECTION 7 - THE SECTOR LEVEL IMPACT OF BST 60

7.1 INTRODUCTION 60

7.2 REGIONAL DIFFERENCES IN THE ALBERTA DAIRY INDUSTRY 60

7.3 MODEL RESULTS 62

7.4 NUMBER OF COWS 63

7.5 FARM NUMBERS AND STRUCTURE 63

7.6 MILK PRICES 64

7.7 QUOTA VALUE 64

SECTION 8 - CONCLUDING COMMENTS 65

REFERENCES 67

APPENDIX 71

TABLES

TABLE 6.1 ALTERNATIVE FEEDS AND NUTRIENT CONTENT PER KILOGRAM OF FEED: (100% DRY MATTER BASIS)....47

TABLE 6.2 NUTRIENT REQUIREMENTS FOR 28.3KG. OF MILK OUTPUT PER COW PER DAY..47

TABLE 6.3 AVERAGE DAILY RATION PER COW (NO BST)....48

TABLE 6.4 FEEDING BUDGET PER DAIRY COW (NO BST)....48

TABLE 6.5 DAIRY ENTERPRISE BUDGET FOR THE REPRESENTATIVE FARM (NO BST)....49

TABLE 6.6 NUTRIENT REQUIREMENTS FOR 32.54KG. OF MILK OUTPUT PER COW PER DAY WITH BST....51

TABLE 6.7 AVERAGE DAILY RATION PER COW (WITH BST)....51

TABLE 6.8 FEEDING BUDGET PER DAIRY COW (WITH BST)....52

TABLE 6.9 PARTIAL BUDGET ASSUMING ADOPTION OF BST AND REDUCTION OF HERD SIZE TO MAINTAIN CURRENT REVENUE FROM MILK SALES (63 COWS)....55

TABLE 6.10 PARTIAL BUDGET ASSUMING ADOPTION OF BST (EXPANSION OF QUOTA).....56

TABLE 7.1 PERCENTAGE DISTRIBUTION OF DAIRY COWS BY REGION IN ALBERTA, 1987...61

SECTION 1 - INTRODUCTION

1.1 BRIEF BACKGROUND

Rapid technological developments in general and particularly in biotechnology have had a great impact in the agricultural sector throughout the 20th century. These changes in technology have caused dramatic increases in productive capacity. The development of recombinant Bovine Somatotropin (BST) and its commercial introduction has potentially significant implications for the dairy industry of Alberta in particular and Canada as a whole.

BST is a naturally occurring hormone that stimulates milk production in cattle. Recent advancements in biotechnology have led to a low cost method of synthesising BST. In November 1993, the US Food and Drug Administration (FDA) approved the use of BST for commercial purposes after reviewing the product for nine years. However, recombinant BST has not been approved for commercial use in Canada, as the government is not yet convinced of the safety of the animal-food products for humans[1]. In addition, the safety of the BST-supplement to the target animals, and the safety of using BST in the environment is not clearly known. In addition to these concerns, there are some uncertainties associated with this technology in terms of the impact on the dairy industry.

---

[1] Application for approval to commercially introduce BST into Canada was turned down by Health Canada in January 1999. However, this is not to say that it will not be approved at some point in the future.

1.2 STATEMENT OF ECONOMIC PROBLEM

Bovine Somatotropin, also known as Bovine Growth Hormone, is a unique product for the dairy industry due to its ability to affect milk yield almost immediately with low capital requirements. This makes BST commercially attractive, in principle, to producers in the dairy sector. However, this technology also raises a great deal of uncertainty for both farmers and policy makers, as the long-term economic and biological effects are not clearly known.

Some of the important issues to be addressed when a new product enters the industry are the probable consumer reaction and the acceptance by the producers to adopt this technology. It is likely that some producers will not find BST profitable due to the higher degree of management associated with it to ensure efficiency gain. However, those producers with better technical and management skills will find BST as an opportunity to expand production and profit based on their overhead structure (Nicol,1989). Both groups of producers face uncertainty about the impacts of BST adoption on their own costs, product prices, and quota values.

Another uncertainty surrounding BST is the health concern expressed by consumer groups. This is based on concerns over possible effects on dairy products. This concern will certainly influence whether BST will eventually be approved for commercial use in the Canadian dairy industry. The entire industry may stand a risk of reduced demand if consumers still remain skeptical and have health concerns about the products of BST. This will adversely affect domestic milk production in particular and the dairy industry as a whole. Also, of concern to both producers and policy makers is the uncertainty surrounding the potential impacts on prices of dairy

products and quota values, farm and cow numbers, and farm structure. This paper addresses these issues and questions.

1.3 OBJECTIVES

This paper has three main objectives. First, the biological and economic literature pertaining to BST is reviewed and potential farm-level adoption scenarios are identified for Alberta dairy producers. A second objective is to develop an empirical framework which could be used to assess the economic impacts of BST adoption at the farm level. Finally, a framework will be established which could be used to assess the effects of BST adoption on the Alberta dairy sector, in terms of milk prices, quota values, farm numbers, etc.

1.4 REPORT OUTLINE

The remainder of this report is divided into seven sections. The second section provides a review of BST, in terms of the effects on dairy cows, milk production, feed requirements, health and longevity, and reproductive capacity. Possible farm-level adoption scenarios are identified in this section. The third section provides a review of the economic literature related to BST. It highlights some of the studies done on BST, the methodology used and results obtained from the studies. Section 4 identifies and discusses an appropriate theoretical model that can be used to explain the economics of BST adoption. The issue of market quota and risk will be considered in the context of this model. Section 5 will identify and discuss a farm-level empirical model that is appropriate for use in achieving the second objective of

the study; that is, an assessment of the farm-level economic impacts of BST adoption. Section 6 provides an initial empirical analysis of BST adoption for a representative farm, using partial budgeting. Break even analysis is also used in this section. Section 7 deals with the sector-level model that is capable of assessing the effects of BST on quota values, milk prices as well as the future structure of the dairy industry in Alberta. The last section provides a summary and some concluding comments.

SECTION 2 - BOVINE SOMATOTROPIN (BST)

This section introduces BST in terms of its functions and effects on dairy cattle. The effects of BST on milk production and feed intake by the animals are reviewed in this section, as are the health and reproduction effects. Finally, possible BST adoption scenarios by producers will be discussed in this section.

2.1 WHAT IS BST?

Somatotropin is a hormone produced in the pituitary gland of all mammals. This hormone regulates growth and metabolic activities in the species for which the Somatotropin is structured. Bovine Somatotropin (BST) is the Somatotropin specific to the bovine species of which the cow is a member. This growth hormone has been known since 1930 and the ability of supplemental injections of BST to increase the milk production of dairy cows was reported as early as 1937 (Asimov and Krouze, 1937). However, at that time the only source of supplementary BST was the pituitary glands of slaughtered cattle. The daily injection dose of BST needed to stimulate increased milk production required an extraction from approximately 200 cows (Trelawny, 1986), which made the economics of BST collection in sufficient quantities to support widespread adoption by dairy farmers unfavourable.

Recent advances in biotechnology have made the synthetic production of BST commercially feasible. The process begins by extracting the gene responsible for BST production from a cow's pituitary gland and implanting it into Escherichia coli bacteria. These bacteria produce large quantities of the hormone when cultivated

under standard fermentation procedures (Baile et al., 1987). Subsequent technical research has shown that the resulting recombinant methionyl bovine Somatotropin is as effective as pituitary-derived Somatotropin (Bauman et al., 1982) in terms of its function. These methods of producing BST have made its widespread adoption economically and commercially feasible.

2.2 HOW BST WORKS

Daily injections of BST, over a full lactation, increase daily milk production and lactation efficiency (Adashi et al., 1989; Isaksson et al., 1985). Studies have shown that the improvement in milk yield can range from 10-40%, and occurs with insignificant changes in milk composition.

When milk production is increased, extra nutrients are needed by the mammary glands to provide the raw materials and energy to make milk. Somatotropin coordinates the metabolism of various body organs and tissues in a manner that supports the increased nutrient use by the mammary glands.

Glucose metabolism illustrates the coordinated manner in which BST alters tissue processes. Glucose is a carbohydrate which is used as an energy source by many tissues. It is also used for milk synthesis (primarily for production of milk sugar). The liver is responsible for producing nearly all of a cow's daily glucose requirement and the mammary glands typically use about 85 percent of this total. With BST-supplementation, the uptake of glucose by the mammary glands increases in a manner parallel to the increases in milk production. This increased use of glucose for milk synthesis is accommodated by whole-body adjustments, through

increased glucose production by the liver and reduced glucose use for energy by other body tissues. In part, these adjustments occur because BST alters the response of tissues to acute signals (e.g., insulin), thereby allowing a greater allocation of glucose for milk synthesis while still maintaining normal body functions. Without such adjustments in metabolism, initiation of BST supplementation would cause glucose use to exceed that which is available, resulting in ketosis and death.

The adjustments in tissue lipid metabolism depend on the nutritional status of the cow at the time that BST-supplementation is initiated. Normally, if a cow's nutrient intake is greater than her requirements, the excess nutrients are used to make body fat. BST administration causes adipose tissue to reduce its use of nutrients to synthesize body fat and allows for reallocation of these nutrients to support increased milk production. A different metabolic adjustment occurs if the cow's nutrient intake is equal to or less than her requirements. In this instance, Somatotropin directs adipose tissue to mobilize deposits of body fat so that these energy reserves can be used to support increased milk production. In both situations, these adjustments involve alterations in adipose tissue response to acute signals (e.g., insulin and other hormones that affect lipid metabolism). These allow the use of body fat reserves to be coordinated with changes in the animal's need for and availability of nutrients. Over time, BST treated cows gradually increase their feed intake so that stores of body fat are replenished during the lactation cycle. This replenishment occurs under a wide range of dietary conditions (Bauman, 1989; Chalupa and Galligan, 1989; Chilliard, 1989). If these adjustments in lipid metabolism did not occur, cows would

become emaciated, decrease their milk production, and be less efficient in their use of feed for milk production.

The regulation of metabolism by BST involves a variety of hormones such as insulin, glucagon, somatostatin, and insulin-like growth factor-1 (IGF-1). Insulin and glucagon are hormones responsible for homeostasis of blood glucose, which serves as an essential substrate for synthesis of milk lactose, milk fat and milk protein. Blood glucose also serves as the osmotic regulator for milk volume (Adashi et al., 1986; Chirgwin et al., 1979; D'Ercole et al., 1984).

In addition to the direct metabolic effects coordinated by BST, Somatotropin indirectly affects the mammary gland via its impact on other controlling compounds (e.g., somatomedins such as IGF-1). Insulin-like Growth Factor-1 (IGF-1) plays a role in an animal's growth and development and mediates many of the effects of Somatotropin growth. IGF-1 has also been shown to directly stimulate milk secretion in rodents (Glim et al., 1988). Injection of BST in dairy cows results in an increase of IGF-1 concentration in the blood and in mammary tissue, which supports the concept of direct action of BST on IGF-1 concentrations.

2.3 BST EFFECTS ON MILK PRODUCTION

Studies of milk production response to BST supplementation have indicated a potential increase from 20% (Kennelly et al., 1986) to 40% (Bauman et al., 1985). The potential increase depends on factors such as method of injection, duration of supplementation and the point in the lactation cycle at which the BST is administered. These results have also been obtained under research conditions where

the animals are handled under a high level of management and are given individual attention. The increase in average daily milk yield within commercial dairy herds is expected to be approximately 10-15% based on observation of dairy cows of different breeds, genetic potential, parity and geographical locations (Kennelly, 1994).

There may be variations in the BST response for individual cows. However, this could be attributed to differences in management, herd health, milking practices, feeding, etc. Hence it may be concluded that, with adequate management, dairy cows will always boost milk production when treated with BST regardless of their genetic make up in terms of both breed and milk production potential (Kennelly, 1994). Milk production increases from the use of BST are due to alterations in the biogenetic efficiencies of the cow. Production increases could therefore be attributed to improved digestibility of the feed, alterations in the biogenetic efficiencies of milk synthesis or partitioning of nutrients away from the body tissues to the mammary gland for milk synthesis (Peel and Bauman, 1987). Also, the effects of Somatotropin treatment are predominantly in nutrient partitioning and the specific changes which occur are similar to those occurring in genetically superior cows.

Marked improvement in persistency of lactation occurs in cows receiving BST (Chalupa and Galligan, 1989; Chilliard 1989; Peel and Bauman, 1987). Supplementation with BST not only results in an immediate increase in milk yield, it also reduces the normal decline in milk yield during the lactation period. Milk yield gradually increases during the first few days following BST treatment, peaking at about the sixth day (Johnson and Hart, 1986; Peel and Bauman, 1987). Maximum

milk response is achieved with a BST daily dose of approximately 30 to 40 milligrams (mg), beyond which no further increase occurs even at doses that are several-fold higher (Kennelly, 1994).

Response to BST varies according to stage of lactation. In general, the milk response is small or negligible when BST is administered in early lactation; that is, the interval immediately postpartum, before peak milk yield (Bauman, 1987). The biological basis for this low response relates to the nutrition/endocrine status of the animal during this interval.

2.4 BST EFFECTS ON FEED REQUIREMENTS

BST use in dairy cows results in improved production efficiency (milk per unit of feed) as the nutrients required for maintenance are reduced relative to the total nutrient intake. This is often referred to as dilution of maintenance. Many studies, (e.g., Adashi et al., 1986; Kennelly, 1994) have shown that dairy cows treated with BST adjust their feed intake to compensate for the increased milk production. An injection of 10.3-20.6 mg of BST results in an average increase in dry matter intake of 6.9% to 12.1% (Kennelly, 1994). The intake of crude protein follows the same pattern as that of dry matter intake (Adashi et al., 1986). However, BST treatment is shown not to have any effect on dry matter intake for heifers (Kennelly, 1994).

One of the major problems associated with BST use is proper ration balancing. All nutrients must be provided in adequate quantity and quality to meet the metabolic demands of the cow given her reserves, and the desired levels of

depletion over the lactation. The ration should therefore have a greater concentration of energy and proteins, which are vital for the maintenance of the body and enhancement of the production response (De Boer and Kennelly, 1988). Research by Chalupa and Galligan (1989) on the quantity of feed requirements for BST-treated cows shows that the feed requirements increase marginally due to the increased milk production per cow. A linear program (LP) model was used to estimate a balanced dairy ration for the higher producing dairy herd. It was found that the nutritional requirements for BST-treated cows are the same as they are for naturally high producing cows. The reasons are as follows; first, digestibility of dry matter, carbon, nitrogen, and energy are not altered when lactating cows are receiving BST. Second, bioenergetic studies have demonstrated that BST does not alter energy expenditure for maintenance or for the synthesis of a unit of milk (Bauman, 1989; Chalupa and Galligan, 1989).

On the question of how BST affects feed intake in milk production, Bauman et al. (1985) experimented using both pituitary and recombinantly derived BST. They reported that with a 20.6mg daily dose of BST, milk yields increased by 16% with the pituitary derived BST and by 36% with the recombinantly derived BST. Net energy intake for the recombinantly derived BST group was also found to be 16% greater than that of the control group.

Burton et al. (1987) determined that with a 25mg daily dose of BST over 266 days, cows had a milk yield increase of 18% combined with a 5% increase in dry matter intake. Soderholm et al. (1988) found a milk yield increase of 25% resulting from a daily dose of 20.6mg, as used by Bauman et al. (1985), with a 10% increase

in the dry matter intake. De Boer et al. (1988) had an overall increase of 11.8% in milk yields for a group of dairy cows and first lactation heifers with an increase in the intake of feed concentrates of 12.5%. This result was obtained from a daily BST dosage of 20.6 mg.

The results of these studies clearly confirm the fact that BST has the potential of increasing milk production but that the effect will surely depend on the feed intake. In addition, the magnitude of the impact will depend on the type of the BST; that is, whether it is pituitary derived or recombinantly derived.

McCutheon et al. (1989) studied BST effects as the quality of herd nutritional management varied over the course of the 26-week treatment period. Cows were fed only pasture, and milk responses to BST were over 18% in the spring when pasture supply was adequate, declined to zero during the summer drought, and were again significant during the fall. They conclude that BST is not magic and as such if cows are given an inadequate amount of feed or fed a diet that is not nutrient-balanced, the magnitude of the response to BST will decrease accordingly.

No special diets or unusual feed ingredients are needed to obtain a milk response to BST. Substantial milk responses have been observed on diets ranging from pasture to forage and concentrates. Overall, however, the dairy cow receiving BST has a greater total nutrient requirement because she is producing more milk. She has a higher productive efficiency because a larger proportion of her total nutrient intake is used to make milk.

2.5 BST EFFECTS ON COWS' HEALTH

BST administration is believed to have insignificant effects on the health of the cow (Kennelly, 1994). Catastrophic effects such as the incidence of ketosis (underproduction of glucose), fatty liver, crippling lameness, milk fever (feverish disorder following partition), mastitis (inflammation of the udder), sickness, suffering, and death have been postulated to occur with BST (Phipps, 1989; Ferguson 1990). However, no such effects have been observed with BST-supplementation of dairy cows in any scientifically valid published studies, nor have more subtle health effects been in evidence.

Animal stress is more difficult to evaluate than disease. However, it can be assumed that although dairy cows under BST treatment may increase their stress level, this level may not be more than that normally experienced by cows producing similar levels of milk due to genetic progress.

Of course, the cow's health depends on the quality of management, and feed must be reformulated to meet the more complex nutrient demand of BST-treated cows. The absence of better quality diets for the animals will only reduce the production response from BST, and may also result in increased incidence of reproductive disorders and other health related problems that are naturally associated with improper dieting (Kennelly, 1994).

2.6 BST EFFECTS ON REPRODUCTIVE CAPACITY

As noted earlier, a high level of nutrition management is essential for maximum effect of BST on treated cows. Failure to provide the animals with quality feeds is likely

to increase the incidence of reproductive disorders. The reproductive performance under BST administration may be impaired, especially over several lactations (Kennelly, 1994).

Treating cows with BST has no apparent effects on mortality, twinning, or sex ratio. Also, birth weights of calves born after the first, second and third lactation are not influenced by BST treatment and the weight does not increase with subsequent lactation. The level of BST dosage also does not affect the health of the cows or calves (Kennelly, 1994).

The effects of BST on reproductive variables such as pregnancy rate (proportion of cows becoming pregnant) and days open (i.e., days from parturition to conception) is of much interest to producers. Reviews by Ferguson and Skidmore (1989), Noakes (1991), and Phipps (1989) have summarized the results for several studies that address reproduction factors. In general, they indicate that BST supplementation results in a decreased pregnancy rate. Days open also increase slightly in BST supplemented cows, according to most studies. It is well established that decreased pregnancy rate and increased days open are associated with increased milk yield (Butler and Smith, 1989). The decrease in pregnancy rate is also related to the increase in milk yield rather than the dose of BST (Ferguson and Skidmore, 1989). Thus, the effects of high milk yield on reproductive performance appear to be the same whether the high yield was due to the use of BST or due to genetic progress (Hard, 1988).

2.7 ADOPTION SCENARIOS

The impact of BST on dairy farm management and performance is at least partly influenced by the method of adoption. Specifically, how long is it administered, and to which cows? There are several possible scenarios that may be considered in a study of BST adoption. Two adoption scenarios will be considered in the paper, as follows:

1. Using the BST only on high producing cows during the mid and late lactation for a period of about 215 days based on the quota levels and the possibility of purchasing extra quota.
2. Using the BST on all mature cows during the mid and late lactation for a period of 215 days, based on the quota levels and the possibility of purchasing extra quota (i.e., a 100% adoption of BST for the farm's mature cows).

Due to the potential risk on the use of BST that can be perceived by dairy producers, it is possible that some producers would rather not treat all animals with BST. This is a way to reduce the potential risk that may be associated with the use of the BST. However, some producers may want to adopt BST for use on all of the available cows. Also, as the impact of the BST is more significant on mature cows than heifers (Kennelly, 1994), the dairy producers are more likely to use the BST on mature cows than on heifers.

As mature cows within any particular herd do not have an equal milk yield, due to age or genetic make up, they can be grouped into high producers, medium producers and low producers. As the ultimate goal is to increase milk production, and response to BST seems to be equal across high, medium and low producers, it is assumed that producers would adopt BST for use in all of the aforementioned groups to capture any benefits of the BST technology.

Trial results indicate that it is feasible to administer BST only during mid and late lactation (Nicol, 1989). The maximum benefit from the BST treatment program, in terms of increased milk production, occurs from day 80 to day 200 of the lactation (Nicol, 1989). This is because, prior to the 80th day, the cow will still be accelerating her own metabolic production systems for the new lactation. BST administration after 200 days will not yield better results as the cow is in the declining portion of the lactation. The metabolic system in the cow after 200 days shifts from milk production to the final development of the fetus (Nicol, 1989). In both adoption scenarios, the BST would be administered only during mid and late lactation, which is approximately 215 days.

In both adoption scenarios (using BST on all cows or only on the high productive cows), the producers can have the choice to acquire extra quota to compensate for the extra milk output or cull some low-producing animals. Increased culling may temporarily affect beef prices. However, this will depend on the proportion of producers adopting BST in this manner. Any milk produced beyond the quota level will be sold at the "world price", which is lower than the price paid for in-quota milk. Producers will have the choice of either providing extra milk output at the world price, or reducing the number of cows, in the absence of purchasing any extra quota.

SECTION 3 - LITERATURE REVIEW

Numerous studies that address the effects of BST on milk yields, feed requirements, management and other related requirements of the dairy industry in various regions have been undertaken. The results from some of these studies are summarised below.

Although numerous researchers and dairy producers agree that BST adoption has the potential to increase returns, one unanswered question is which farm categories will receive the greatest benefits and under what circumstances. Trelawny (1986) conducted a study on this issue for Canadian dairy farms. In his study, he used three representative farms categorised by different levels of capital and management inputs. Using a linear programming model to determine each farm's financial performance based on the available resources, he then assumed the adoption of BST into the model. This was designed to examine the effects of BST based on the changes in variable returns. He concluded that the increase in short term net returns from adopting BST ranges from 5-15%, which excludes the cost of the drug. These results however depend on the combination of farm resources and yield responses. It was concluded that BST would favour a manager with superior feeding skills.

Oxley et al. (1989) conducted a study to determine the potential long run economic impacts of BST on the Ontario dairy industry. The objective was to measure the effects of BST on dairy producer numbers, quota values and economic welfare. A microeconomic numerical simulation model was developed for the study. The model was used to estimate the equilibrium conditions for specified values of the explanatory

variables, which included milk output and factor prices, product prices and the current technology. This model was then altered to simulate the impact of BST technology. The differences between the set of estimated values represented the impacts of BST technology. They concluded that widespread adoption of BST in Ontario would potentially reduce the number of dairy producers by 5%. They noted that there would be a 23% increase in quota values and an annual increase in producer surplus of $49 million.

Fallert (1987) did a study on the aggregate level impacts of BST for the US dairy industry. The objectives of the study included the following:

1. Comparing the national effect of commercially adopting BST with a non-BST situation on total milk supplies, commercial use of milk and dairy products, milk prices, and government purchases of excess dairy products under the US dairy price support program.
2. Estimating benefits and costs of BST on the farm for different farm sizes in different regions.
3. Projecting financial conditions of dairy farms by farm size and region with and without BST for four different dairy policy scenarios.
4. Predicting the BST-induced structural change in dairy farms by size and region.
5. Assessing likely effects on the US competitive position in world dairy markets if BST is commercially available in other countries but not in the United States.

In his study, Fallert (1987) conducted extensive meetings with researchers in government, universities and private sector to critique the various aspects of BST use and research. He then elicited technical knowledge and opinions of experts and developed a consensus, and did an extensive survey of the BST literature to arrive at potential yield

assumptions and adoption rates. He linked two computer models to study the operation of the dairy sector and to simulate adoption and non-adoption scenarios with different policy assumptions. These models were the national model of the dairy industry, which simulated aggregate milk supply, demand, prices and government purchases, and a farm level model based on 150 individual representative farms. This was developed to evaluate the operation of typical dairy farms by size and region.

Fallert concluded that although BST would be profitable for individual dairy farms to adopt, widespread adoption would increase milk supplies and reduce prices if supports were allowed to adjust. According to these results, the lower prices would inevitably drive some inefficient dairy operations out of business whether or not BST were adopted. It was also found that the relative size of farms and regional locations for milk production would not change and that the number of dairy farms in US would decrease as a result of BST. These findings were consistent with those of Oxley et al. (1989).

An assessment of how BST may impact on Minnesota's share of the US dairy industry was conducted by Helming and Hammond (1991). Factors considered in this study included the total cow numbers, milk production per cow and the total milk supply. The study used the National Economic Milk Policy Impact Simulator (NEMPIS). Helming and Hammond concluded that, regardless of whether BST were adopted or not anywhere in the United States, the Minnesota dairy industry would continue to fall behind in terms of production per cow. In addition, the industry would experience a decline in total milk production in Minnesota. On the other hand, if BST were adopted only in Minnesota and Wisconsin, then substantial production per cow gains would boost the dairy industry in these regions. The study also concluded that if BST were approved

in the rest of US and consumer demand for milk and milk products was not altered significantly because of the product, prices of milk and milk products would likely fall. Non-adopting farms would increasingly be unable to cover variable costs, which would compel them to either exit from the industry or adopt BST or other technologies to make themselves more competitive.

Jeffrey and Eidman (1994) used stochastic simulation methods to assess the impact of BST adoption on performance and structure for representative dairy farms in Minnesota. They concluded that the adoption of BST enhanced financial performance irrespective of the initial herd size level of milk production and debt. Adoption of BST also reinforced incentives for expansion and specialisation by dairy farms in the upper Midwest of US.

A study by Stennes et al. (1990) on BST and the Canadian dairy industry examined the impacts of BST at the firm and aggregate industry level, both regionally and nationally. In the study, the Canadian Regional Agricultural Model (CRAM) was used (Stennes et al. 1990). Based on a BST adoption rate assumption of 68% of overall dairy farms in British Columbia, it was concluded that there would be a 5% decrease in the dairy herd size and a 5% increase in dairy sector producer incomes if prices remained at 1986 levels.

Nicol (1989) investigated the impacts of BST on Alberta producers from an industry wide perspective using a combination of budgeting and linear programming models. Based on the analysis, he concluded that BST use in Alberta could produce the following impacts:

1. No major shifts in regional comparative advantage.

2. A small shift of production capacity from Edmonton to the south based on the relative concentration of less efficient producers.
3. A maximum of 8.5% reduction in cow (and producer) numbers.
4. Little if any consumer benefits in the form of lowered dairy product prices.
5. A significant producer wealth generation effect as the adopting producers bid up quota prices in an effort to maintain facility use at capacity levels.

In his study, Nicol identified that the time of adopting the new technology by farmers was very important. First adopters or innovators would gain the economic benefit from the technology before the market could adjust prices to reflect any long run changes in supply resulting from the commercial use of the BST. For example, the innovators or the first adopters would increase their milk production and reduce their cost per unit output and would have the opportunity to buy the quota needed to maintain their production capacity before late adopters started using the technology and eventually bid up the quota exchange price.

SECTION 4 - THEORETICAL MODEL

The purpose of this section is to derive a theoretical model suitable for examining adoption of BST by individual dairy producers. Relevant production economics theory is briefly outlined. The basic characteristics of problems that can be solved using linear programming (LP) methodology are discussed. In addition, the basic assumptions underlying the use of linear programming models to solve problems of profit maximization are briefly mentioned in this section.

4.1 PRODUCTION ECONOMICS THEORY

A production function describes the technical relationship that transforms resources (inputs) into commodities (outputs). A netput function for a multi-product, multi-input technology is written as:

$$f(y_1, y_2, x_v, x_f) = 0 \qquad (4.1)$$

where y_1 is the vector of outputs not subjects to quotas, y_2 is the vector of outputs that are subject to quotas, x_v is the vector of variable inputs, and x_f is the vector of inputs available in fixed amounts.

Examples of these fixed inputs for agricultural production might include land or quota. Details of the neoclassical production function can be found in many textbooks on production economics (e.g., Doll and Orazem, 1978). It is assumed that producers behave rationally and as such choose goals consistent with their preferences. In this study, it is assumed that a rational producer will operate in a manner which will enable him to maximize returns subject to the limits imposed by this production relationship. It is also

assumed that individual producers operate within a perfectly competitive market; that is, they take output and input prices as given, and their production decisions do not influence these prices. Suppose a producer produces a single output y which may be sold at a market price of p. The total revenue *(TR)* function will be written as:

$$TR = py \tag{4.2}$$

The cost of production is the sum of fixed and variable costs:

$$TC = vc + fc = wx \tag{4.3}$$

where TC is the total cost, vc is the variable cost and fc is the fixed cost, w is the vector of the input cost and x is the vector of inputs including both variable (x_v) and fixed(x_f) inputs. The producer's profit is equal to the total revenue *(TR)* minus the total cost *(TC)*:

$$Profit = TR\text{-}TC = py\text{-}wx \tag{4.4}$$

Now suppose that the producer produces multiple outputs. Some of these outputs *(y_1)* are not subject to quotas while others *(y_2)* are subject to quotas (e.g., milk). The profit maximization problem can now be written as follows:

$$\textit{Maximize profit: } p'_1\, y_1 + p'_2\, y_2 - w'_v\, x_v - w'_f\, x_f \tag{4.5}$$

$$\textit{subject to}: f(y_1, y_2, x_v, x_f) \leq 0$$

$$x_f \leq z$$

$$y_2 \leq Q$$

where y_1 is the vector of outputs not subjects to quotas (and p_1 is the corresponding output price vector), y_2 is the vector of outputs that are subject to quotas (and p_2 is the corresponding output price vector), x_v is the vector of variable inputs (and w_v is the variable input price vector), x_f is the vector of inputs available in fixed amounts (and w_f

is the unit cost vector for fixed inputs), z is the vector representing availability of fixed inputs, Q is the vector of farm level quotas, and $f(y_1,y_2,x_v,x_f)$ represents the netput function for the multi-product, multi-input technology utilized on the farm.

The problem of constrained profit maximization can be solved through use of the Langragian method, as follows[2]:

$$L(y_1, y_2, x_f, x_v, \lambda_Z, \lambda_Q, \lambda_N,) = p'_1\, y_1 + p'_2\, y_2 - w'_v\, x_v + \lambda_Z(z - x_f) + \lambda_Q(Q - y_2) + \lambda_N(0 - f(y_1, y_2, x_v, x_f)) \qquad (4.6)$$

The first order conditions for the maximization of the objective function subject to the constraints are the Kuhn-Tucker conditions, as follows:

$$\frac{\partial L}{\partial y_1} = p_1 - \lambda_N\left(\frac{\partial f}{\partial y_1}\right) \le 0, \qquad y_1 \ge 0, \qquad \left(\frac{\partial L}{\partial y_1}\right) y_1 = 0 \qquad (4.7)$$

$$\frac{\partial L}{\partial y_2} = p_2 - \lambda_Q - \lambda_N\left(\frac{\partial f}{\partial y_2}\right) \le 0, \qquad y_2 \ge 0, \qquad \left(\frac{\partial L}{\partial y_2}\right) y_2 = 0 \qquad (4.8)$$

$$\frac{\partial L}{\partial x_v} = -w_v - \lambda_N\left(\frac{\partial f}{\partial x_v}\right) \le 0, \qquad x_v \ge 0, \qquad \left(\frac{\partial L}{\partial x_v}\right) x_v = 0 \qquad (4.9)$$

$$\frac{\partial L}{\partial x_f} = -\lambda_Z - \lambda_N\left(\frac{\partial f}{\partial x_f}\right) \le 0, \qquad x_f \ge 0, \qquad \left(\frac{\partial L}{\partial x_f}\right) x_f = 0 \qquad (4.10)$$

$$\frac{\partial L}{\partial \lambda_Z} = z - x_f \ge 0, \qquad \lambda_z \ge 0, \qquad \left(\frac{\partial L}{\partial \lambda_z}\right) \lambda_z = 0 \qquad (4.11)$$

$$\frac{\partial L}{\partial \lambda_Q} = Q - y_2 \ge 0, \qquad \lambda_Q \ge 0, \qquad \left(\frac{\partial L}{\partial \lambda_Q}\right) \lambda_Q = 0 \qquad (4.12)$$

$$\frac{\partial L}{\partial \lambda_N} = 0 - f(y_1, y_2, x_v, x_f) \ge 0, \quad \lambda_N \ge 0, \qquad \lambda_N\left[0 - f(y_1, y_2, x_v, x_f)\right] = 0 \quad (4.13)$$

The Lagrange multipliers obtained from the solution of a primal problem indicate the shadow prices for the constraints. For each variable in each category (i.e., variable and fixed resources), there corresponds a marginal condition to be satisfied by the optimal solution. Each of the variables must as well be non-negative. Although the use of netput function notation complicates the interpretation of conditions 4.7 to 4.13, basically they ensure that the standard marginality conditions associated with input use and profit maximization are set. Specifically, inputs are used in production to the point where their value marginal products are no greater than their marginal factor costs.

4.2 LINEAR PROGRAMMING MODELS

The problem that involves constrained maximization using the Langragian function is usually solved by non-linear programming as either the objective function or the constraints are non-linear. For example, in general a netput function:

$$y = f(y_1, y_2, x_v, x_f) \tag{4.14}$$

will be a non-linear function.

If however, the constrained optimization problem can be expressed in linear form, linear programming may be used. Specifically, the profit maximization function can be cast in a linear programming (LP) framework to express the basic production relationships while providing the possibilities of adjusting the model to suit changes like quota, price, addition of a new input, etc. The problem can easily be solved on computer using appropriate software (e.g., Microsoft Excel).

---

[2] Note that the fixed cost term ($w_f x_f$) is excluded from the equation 4.6, as it is a "constant".

A linear programming model is a mathematical technique for solving a problem that is characterized by the following attributes:

1. A linear function or objective to be maximized or minimized;
2. Limited resources to be used to satisfy this objective;
3. Availability of numerous means of using the resources.

The basic premise of linear programming (LP) procedure is optimization of a specific outcome variable, which depends on the values for decision variables. This optimization is done subject to a set of restrictions or constraints limiting the decisions that can be made. Assuming that the producers exhibit profit maximization behavior and as such the objective function of the model will be profit maximization, the model for the profit maximisation may be defined as:

$$Max\ Z = \Sigma C_j X_j \qquad (4.15)$$

Subject to

$$\Sigma a_{ij} X_j \leq bi \quad for\ i = 1....m$$

$$X_j \geq 0 \quad for\ j = 1....\ n$$

where;

X_j = the level of the jth production activity.

C_j = the per unit return to the unpaid resources (b_i) for the jth activity

a_{ij}= the amount of the ith resource required per unit of the jth activity

b_i = the amount of the ith resources available

Z = profit function (in the short-run)

The basic assumptions underlying the use of linear programming models in agricultural production problems are as follows:

1. LP production activities should be represented by fixed-proportion technology (proportionality);
2. There must be a finite number of activities;
3. An activity can produce any level of non-negative output (divisibility);
4. The output of all activities should sum up to the total output of the farm (additivity).

4.3 RATIONALE FOR USING LINEAR PROGRAMMING

In typical production practices, producers tend to use inputs in "regular" proportions and often some inputs cannot be substituted for others. This makes the assumption of a fixed-proportions production function more reasonable. We assume that there is no "substitute" for the BST technology in milk production (at least in the short term), and BST will be used in fixed proportions with the other inputs. These assumptions make the use of LP to solving the problem appropriate.

A linear programming model is chosen as the empirical framework for this problem (i.e., adoption of BST). This is because LP provides not only information on the best way of allocating resources and the best production, marketing or financial plan, but also additional information concerning the implicit value of fixed resources used in the plan. Other analysis procedures (e.g., simulation) are able to provide this information only with great difficulty and significant effort. For this reason, the LP procedure is preferred for use in this analysis. LP can easily be used to evaluate how an optimal solution will change if changes occur in product or factor prices, as well

as policy changes (e.g., quota). Using LP for the problem will enable us to identify the best adoption scenario for the BST.

SECTION 5 - EMPIRICAL MODEL

The purpose of this section is to identify an appropriate empirical model framework for the maximization problem that conforms to the theoretical production economics model outlined in the previous section. A process for defining representative Alberta dairy farms will be identified and the empirical model structure will be discussed. The potential data sources for the various parameters of the model will be discussed. This will be followed by a discussion of how BST will be incorporated into the empirical model.

5.1 EMPIRICAL MODEL APPROACH

To carry out this research, two major steps have to be taken. First, one has to identify and define operations that are representative of Alberta dairy farms, as well as data representing their capacities and production practices. Second, one must identify the activities and resource constraints, develop the empirical model framework, calculate the necessary input-output coefficients from the collected data and other sources, run the model, make the necessary corrections and re-run the model for a an optimum solution. The data relevant to this project should reflect the differences in the physical and economic productive efficiencies of the producers who are likely to adopt BST technology. Such data can be obtained from sources such as the Alberta Dairy Herd Improvement program, from the annual provincial dairy farm survey sponsored by Alberta Agriculture and Alberta Milk Producers Society, and from researchers who have investigated the technical impacts of BST.

5.2 REPRESENTATIVE FARMS

Alberta has five major dairy producing regions: Southern Alberta, Calgary, Red Deer, Edmonton, and Northern Alberta. The distribution of dairy cattle varies across these regions with Southern Alberta having more “high” producers (i.e., cattle with high milk output) than other regions. In addition, the herd sizes and costs of production are not uniform across these region. Based on these differences, representative farms will be selected from each region for a cross-sectional representation of Alberta dairy farms.

The basic criterion used to define the representative farms is the size of operation (i.e., herd size). Using data on cost of production from the Economics of Milk Production in Alberta (Appleby, 1996)[3] a representative farm can be obtained. For example, the mode for the herd size distribution may be used to define a “representative” Alberta dairy farm. Milk production level is used as a secondary criterion to identify the representative farms. Milk productivity will have an implication on the overall farm efficiency. The representative farms will be based on modal herd size and milk production values from each region to assess the impact of BST adoption in Alberta.

5.3 GENERAL MODEL STRUCTURE

The empirical linear programming model has four main structural components, as follows:

---

[3] The Economics of Milk Production in Alberta (Appleby, 1996) publication provides a summary of the data. The actual survey data would be required to develop representative farms for each region.

1. Specification of the objective function (net return equation).
2. The dairy block, which incorporates model aspects related to the dairy enterprise. This includes the ration formulation, milk production response, quota restrictions, culling and calving relationships, etc. It is in this section that most of the adjustments for BST adoption will be made in the model.
3. The crop block that deals with the specification of crop production levels, a link to dairy feed requirements, and land use based on several factors including agronomic restrictions.
4. The general farm block that specifies labor requirements and hiring and financial resources and other resources that affect both dairy and crop blocks and the farm as a whole.

5.3.1 OBJECTIVE FUNCTION

The objective function, which can be said to represent the goal of the producer, is gross margin (i.e., revenue minus variable costs) from the farm operation. In other words, the objective function of the farmer is to maximize net returns to fixed inputs.

The structure of the objective function includes net returns from milk, beef, and crop sales. The objective function will incorporate the costs of crops such as wheat, oats, alfalfa, canola, barley, flax, and hay. Since it is assumed that more crops may be produced than are needed for the dairy enterprise, crop sales activities are included in the calculation. The objective function for the maximizing model will be expressed mathematically as follows:

$$Maximize\ profit = p'_1\, y_1 + p'_2\, y_2 + p'_3\, y_3 - w'_v\, x_v \qquad (5.1)$$

where y_1, y_2 and y_3 are quantities in of milk(in hectolitres), beef (in kilograms) and crop (in metric tons) sold respectively, p_1, p_2 and p_3 are their respective unit prices, w_v is the variable input price vector and x_v is the vector of variable inputs. The objective function treats the other costs of the dairy operation (e.g., fixed labor, taxes, interest on long term loans) as fixed over the specified time period.

5.3.2 DAIRY BLOCK

The activities that are in this block include cows, heifers, milk production and sales (fluid and industrial milk), and ration ingredients. The ration will be determined by constraints reflecting requirements for energy, crude protein, calcium, phosphorus, crude fiber, etc., and by relative costs and nutrient contents of alternative feedstuffs. BST adoption is considered in this block.

It is assumed that the cows are subdivided into three groups (no[4], low and high producing cows) based on their productivity and the BST will be administered to only the high producers. The proportion of the herd size falling into these three groups will de determined based on Alberta Dairy Herd Improvement data. The number of cows that the farm can handle effectively will depend on the available resources and the quota levels for the livestock products (i.e., milk). The optimal solution, depending on the milk quota level, will determine the number of cows that can effectively be handled on the farm. The culled cows, heifers and calves can be

---

[4] Heifer, calves, cows in dry period etc. This group may also be subdivided in the model due to differences in costs, feed requirements etc.

determined endogenously by cow numbers using specified calving rates and death loss rates.

For the feeding constraints, the ration to be fed must be specified. In addition to energy and protein, the nutrient restrictions may include minimum requirements for crude protein, crude fiber, calcium and phosphorus, and a maximum limitation on non- protein nitrogen. The allowances can be entered directly in absolute amount if the ration quantity to be fed is known. Otherwise, they are specified as either minimum or maximum percentage of the total unknown quantity of ration to be fed. Finally, the maximum voluntary intake of roughage fed per cow is specified based on bodyweight and milk production level.

5.3.3 **CROP BLOCK**

The activities related to crop production include wheat, oats, alfalfa, canola, barley, flax and hay. These crops are grown for feeding and/or sales purposes. The land used in crop production will be limited to the total land available for the farm. The land allocated to the individual crops should be limited by agronomic restrictions. This is because agronomic considerations in crop farming usually have positive effects on the yield. The need for an individual crop based on the quantity of crops required for both sales and feeds will be a determining factor of the plot allocated for it.

5.3.4 **FARM BLOCK**

These activities do not fall into dairy or crops but must be considered in the model. They include labor hiring and financial resource use. The labor resources can

be either endogenous or exogenous. If the number of workers that the farm operation will require is unknown, based on the labor requirements for each unit of the farm activity, the solution will find the effective number of workers and the cost involved. On the other hand, if the number of workers are known, it can be specified as a constraint which will limit labor use to that number.

The financial resources can also be constrained to the amount available or expected to be spent on the farm (if it is known). It can also be made endogenous which the amount required for the farm operation will de determined based on the cost of a unit farm activity, the cost of the capital, and the income per unit activity.

5.3.5 DATA FOR THE LP MODEL

The linear programming model requires available amounts for all resources, which include land, labor, and cows or quota. The land allocated to each crop activity will be determined endogenously. Monthly or quarterly labor requirements must be calculated for the representative farm. In addition, the cost and gross income of each activity, the input-output coefficients of all activities and the corresponding resources must be known for the purposes of the LP model. These coefficients are calculated as the amount of inputs needed to produce a unit output, which of course will depend on the measurement unit for the various activities in the model. The data required for the BST scenarios include: total milk output per cow under BST treatment, cost of BST per cow per day, and daily BST dose.

Data on crop, beef and milk yields, market prices for crops, beef and milk, land, capital, labor, and materials crops and livestock production, proportions of

cows in each category (i.e., high, low and no response to BST), calving and death loss rates can be obtained from Statistics Canada, from the survey data used to develop the representative farms (e.g., Alberta Dairy Cost of Production Survey) or from expert opinion. Prices for BST will be based on US data and converted to Canadian dollars. In addition, other sources of BST information can be obtained from books and articles of technical researchers who have investigated BST.

5.4 INTRODUCTION OF BST INTO THE MODEL

BST will be introduced into the model as a new input (resource) which will be administered to the cows. It is assumed that the cows are subdivided into three groups (no, low and high producing cows) based on their productivity. First, the model for the dairy farm production will be run to determine the optimal combination of activities assuming no BST adoption. This will be the base or control scenario. Secondly, a model which assumes the adoption of BST technology under the first scenario (i.e., BST is adopted for all cows) will be run to determine the optimal production solution and the output level. The two models will be compared and the difference will be considered as the impact of BST adoption for the farm. The input dose and associated cost of BST[5] will be determined based on research report and articles about BST. This will, in turn, affect the milk output from BST treated cows (i.e., coefficients V_{pblpj2}, V_{pbmpj2} and V_{pbhpj2} as shown in the matrix in the Appendix).

---

[5] The BST dose can be either 10.3mg or 20.6mg per cow per day.

The other alternative scenario involves using BST on only the high producing cows. In this case, there will be no BST-affected coefficients for the "low" and "no producing" cows. The quota limit and production per cow will determine the number of cows that the farm needs to hold for optimum returns. In addition, the solution to the adoption on all the scenarios, and that of the adoption on only the high producer scenario will be compared to know which one is recommendable to be practiced by Alberta dairy producers.

For the incorporation of the BST into the model, there should be some adjustments to the model which will include the increase of the minimum ration requirements and milk output. This is due to the increase in feed requirements associated with the BST adoption. The cost of the unit BST will also have to be included in the model. The extra cost associated with the use of BST should be indicated in the objective function model. The cost per unit milk output will have to be adjusted depending on the BST injection dose.

5.5 A LINEAR PROGRAMMING MODEL CONSTRUCTION FOR A REPRESENTATIVE FARM

Appendix A provide a more detailed model structure. It should be noted that the input-output coefficients are distinguished from one another by using the first letter of each activity in place of j. For example, a_{iw} is an input-output coefficient for wheat.

5.5.1 Land Use

It is assumed that the farmer will have a crop mix which may include wheat, oats, alfalfa, canola, barley, flax and hay. Based on the farmer's objective of satisfying farm needs and maximizing net returns, the crop mix is determined endogenously.

The input-output coefficient (i.e., land required to produce a unit output of *jth* crop) a_{ij} for wheat, for example, will be the inverse of the wheat yield. For example, if the yield is 100 tons per hectare, the input-output coefficient will be 0.01. Similar calculations will be done for the other crops and they will be written as coefficients against their respective enterprises. The total area for crops should not exceed the land available (bl) in the optimal solution, as follows:

$$\sum a_{ij} X_{j1} \leq b_i \tag{5.2}$$

or

$$a_{iw}(\text{wheat}) + a_{ib}(\text{barley}) + a_{if}(\text{flax}) + a_{ic}(\text{corn}) + a_{is}(\text{soybeans}) + a_{ih}(\text{hay}) + a_{ip}(\text{pasture}) \leq b_l \tag{5.3}$$

where i refers to *ith* crop activity, X_{j1} represents the enterprise, and 1, 2, and 3 represent the crop, livestock and farm blocks respectively.

5.5.2 Crop Constraints

Agronomic needs and links between crops and feed requirements are modelled as follows:

$$\sum a_{ij} X_{j1} \leq b_i \tag{5.4}$$

where b_i represents the land restrictions for individual crops, due to agronomic reasons (e.g., crop rotation). The linear programming model will determine the structure within the limit of the land available. Similar equations are written for all crops.

5.5.3 Labor Use

Labor use is modelled as follows:

$$\sum a_{tjl} X_{j1} + \sum a_{tj2} X_{j2} - X_{jt} \leq b_t \qquad (5.5)$$

taking t to represent the labor activities, a_{tj1} is the amount of labor, in person-hours required to produce a unit of crop output and a_{tj2} is the labor, in person-hours, required to produce a unit of output in livestock. X_{jt} is the total labor required, in person-hours, which is hired, and b_t is the available total labor for the farm in person-hours. The labor constraints may also be made seasonal. The total labor required for all seasons should be equal to the total labor required for the year (see Appendix A).

5.5.4 Fertilizer Use

Fertilizer use is modelled as follows:

$$\sum a_{lj1} X_{j1} \leq 0 + X_{j3l} \quad or \quad \sum a_{lj1} X_{j1} - X_{j3l} \leq 0 \qquad (5.6)$$

where a_{lj1} is the mineral fertilizer required to produce a unit output of crop j_1 and X_{j31} is the purchased mineral fertilizer.

Some by-products from the livestock (i.e., cow manure) can be used to supplement the fertilizer requirements of the crops. By adding the livestock by-product, the constraint will be rewritten as:

$$\sum a_{lj1} X_{j1} - \sum V_{lj2} X_{j2l} - X_{j3l} \le 0 \qquad (5.7)$$

where v_{lj2} is the amount of organic fertilizer produced from a unit livestock output.

5.5.5. Feed Production and Requirements

Taking h as a suffix for ration activities, the nutrients produced per unit crop are given by V_{hj1} and the nutrient requirement per unit milk output is represented by a_{hj2}. A constraint is written for each nutrient, as follows:

$$\sum a_{hj2} X_{j2} - \sum V_{hj1} X_{j1} - X_{j3h} \le 0 \qquad (5.8)$$

where a_{hj2} is the nutrients required to produce a unit output of livestock product. V_{hj1} will be the amount of nutrients output per unit crop output, and X_{j3h} will also be the feed required to be purchased from elsewhere to supplement the total nutrient requirements. Index j represents the block of individual activities, j1, j2 and j3 represent crops, dairy and farm blocks respectively.

5.5.6 BST Use:

The use of BST to treat the cows can be incorporated into the model by adjusting milk output, feed intake, etc. The parameters that need to be adjusted to reflect the use of BST include extra costs (eg. BST, feed) in the objective function. Input-output coefficients for milk production should also be adjusted to reflect on the use of BST on the animals.

5.5.7 Milk Production

The constraints limiting milk production are as follows:

$$\sum V_{pj2} X_{j2} \leq Q_{pl} \tag{5.9}$$

V_{pj2} is the amount of milk output required which should not be more than Q_{pl} (i.e., quota level). The amount of milk expected to be produced from BST-treated cows should have its own expected amount (Q_{plb}) and that of the non treated should also have its expected amount (Q_{pl}). This will bring out the combination of the two groups to achieve the production objective. The total milk output required can be obtained by summing up the output of the two groups. However, there may also be a possibility of purchasing extra quota to allow for production expansion.

5.5.8 Financial Activities

Gross income is defined as:

$$\sum V_{inc.j1} X_{j1} + \sum V_{inc.j2} X_{j2} - X_{j3(inc.)} = 0 \tag{5.10}$$

(*inc* = income)

taking *inc* to represent the financial income activities. $V_{inc.j1}$ is the gross income obtained from a unit output of jth crop and V_{incj2} is the gross income obtained from a unit output of *jth* livestock. X_{j3}(*inc.*) is the total gross revenue from the farm.

Expenses are modelled as:

$$\sum a_{ex.j1} X_{j1} + \sum a_{ex.j2} X_{j2} - X_{j3(ex.)} = 0 \qquad (5.11)$$

where *ex* represents expenses, a_{sj1} is the amount spent on producing a unit output of jth crop and a_{sj2} is the amount spent on a unit output of *jth* livestock product and $X_{j3}(ex.)$ is the operational capital requirement (e.g., loan required to support production activities). The difference in the cost of BST treated cow and non-BST treated cow will be reflected in this section.

The total net profit, which should be maximized, is modeled as

$$X_{j3}(inc.) - X_{j3}(ex.) = \Pi \text{ (max)} \qquad (5.12)$$

5.5.9 Time

Time is very important in analyzing the effects of BST technology in the dairy sector should it be adopted. This brings about the introduction of dynamic linear programming. This will be done by taking different decisions and formulating a linear programming problem. The decisions taken at different times can be seasonal (i.e., within a year) or annual (i.e., multiple years) in nature. The annual or seasonal blocks will be linked together by labor and financial requirements and each decision taken will depend on the previous decision made. For example, if the decisions are seasonal, the crops harvested in fall will depend on the plot of land sown in spring. For multiple year production plans, annual replacement decisions must be incorporated into the model. The initial decision will be non-adoption of BST, then adoption of BST on only the high producers, and then the adoption of BST on all the animals in the farm. All these

decisions will be in blocks and put together in one model. The changes in the decision problems by the representative farms over time will be reflected through changes in some if not all of the parameters. This will allow the effects of changes in other production technologies to be analyzed with time.

5.6 MODEL PROCEDURE

For achieving the objectives of the study, data of selected dairy farms will be collected from the sources mentioned earlier. A linear programming model will be constructed for each representative farm. The objective function of the model will be profit maximization as it is assumed that producers are inclined to maximizing their profit in a production period. The activities that will be used in the model for the representative farms will include cows and heifer production, crop production, sales and purchasing of feeds, Livestock replacements, milk sales, labor hiring, and Livestock feeding activities. Based on the activities of the representative farm, enterprise budgets will be developed to determine receipts, variable expenses, and fixed expenses for the various enterprises.

The limited resources in the form of land, labor, livestock will be incorporated through appropriate constraints. The respective technical or economical coefficients will be determined based on the available data of the representative farms and market prices. The model will then be solved using a linear programming solver (e.g., Solver in Excel, GAMS) to derive the initial optimal solutions.

5.7 SENSITIVITY ANALYSIS

There is a need for sensitivity analysis to determine the impacts of price changes, quota changes, etc, in the dairy industry. To predict how changes in milk price would affect the optimization solution the price will be varied and the LP problem re-solved for a new optimal solution. In the same way, a change in quota level can also be incorporated into the model for the LP problem to be re-solved until an optimum solution is achieved. Different adjustment in the parameters can be made to see how they will influence the sector. The sensitivity analysis can also give us the range in which the milk prices can change without changing the optimality of the solution. This can be tested by assuming a change in government policy allows a certain percentage change in milk price, which can be either an increase or a decrease in prices. Similar analysis can be done for other parameters.

5.8 OTHER ISSUES

On the issue of the number of cows, the producers will have to make a choice, which will depend on the quota level, their ability and the cost involved to acquire extra quota. In this situation, based on the shadow price from the sensitivity report, it can be determined whether or not it is optimal to buy additional quota and if so, how much should be bought and at what price. With the knowledge of how much is required, the quota level is increased to that level. However, the cost per unit quota will be subtracted from the objective function model.

SECTION 6 - INITIAL EMPIRICAL ANALYSIS

6.1 INTRODUCTION

There are several ways in which the decision to adopt BST may be evaluated. These include linear programming analysis (as discussed earlier), simulation analysis and partial budgeting. Implementation of linear programming or simulation analysis is beyond the scope of this paper. Instead, partial budgeting is used to provide an initial assessment of BST use by Alberta dairy producers. The purpose of this section is to analyze the change (assuming BST adoption), relative to the present situation in an average Alberta dairy, farm using partial budgeting. Break even analysis for this change will also be done. Concluding comments will be made from the analysis.

6.2 EMPIRICAL ANALYSIS

Based on the information obtained from the 1996 publication, The Economics of Milk Production, an empirical analysis of the potential impacts of BST at the farm level in the Alberta dairy sector is carried out. The analysis is based on the assumption that the objective of the producer is to maximize net returns to the fixed resources available on the farm (i.e., family and operator labor, operating capital, dairy cattle, machinery and land). The analysis is conducted using partial budgeting methods.

A partial budget is a convenient and practical method by which “small” changes in revenues and costs as a result of a proposed adjustment can be analyzed (Boehlje et al. 1984). It is a formal and consistent method for calculating the expected changes in profit from a proposed change in the farm business. Partial budgeting involves a comparison of the profitability for one alternative, typically the current situation, with the profitability

for a proposed change or new alternative. The analysis is for a relative small change in the farm plan, so only changes in revenue and expenses are included on a partial budget. The result is the expected change in average annual profit. Since partial budgeting deals with changes that occur in revenues and costs, it is somewhat consistent with economic marginal concepts and marginal analysis involving marginal revenue (MR) and marginal cost (MC) or marginal value product (MVP) and marginal factor cost (MFC).

The only information required to implement partial budgeting is that related to changes in costs and revenues if the proposed alternative is implemented. These changes in costs and revenues can be identified by considering the following four questions:

1. What new or additional cost will be incurred?
2. What current cost will be reduced or eliminated?
3. What new or additional revenue will be received?
4. What current revenue will be lost or reduced?

6.3 REPRESENTATIVE FARM

Using data on costs of production from the Economics of Milk Production in Alberta (Appleby, 1996), a representative farm for the partial budget analysis is developed. This farm represents an "average" dairy farm based on the set of dairy farms sampled for the survey. The resulting farm has a 71 cow herd. Milk production is 28.3 Kg. per cow per day or 8492.05 Kg. per cow per year[6]. The average butterfat level is 3.5 percent. The milk quota level for the farm is 4068.93 hectoliters. The blended milk price obtained by the farmer is $52.50 per hectoliter. (1 hectoliter of

milk $\simeq$ 100Kg. of milk). Budget information for the dairy enterprise is taken from the Economics of Milk Production publication with the exception of feed costs. Calculations for feed costs are discussed below.

Feed costs for the dairy herd are calculated using least cost ration analysis and linear programming. An average ration is derived using the milk production level and composition (i.e., butterfat level) specified above. It is assumed that the cows weigh approximately 650 Kg. Given this information, nutrient requirements for net energy (NE_l), crude protein, calcium, phosphorous and crude fibre are obtained from published sources (National Research Council 1978). Ration ingredients included in the model are alfalfa hay, barley, oats, canola meal and alfalfa silage. Nutrient contents for these ingredients are based on a published "typical" values (National Research Council 1978). Costs for these ingredients are based on feed values used in Appleby (1996). Relevant information required for the LP model of the least-cost ration is shown in tables 6.1and 6.2

A linear programming model is then used to solve for the least cost ration. The various nutrient requirement constraints ensure that the animal's milk production and maintenance needs are met. In addition, limits are placed on the total dry matter consumption based on cow weight and production level. The resulting ration (Table 6.3) includes alfalfa hay, barley and silage[7]. The daily cost of this ration is $ 2.29. Table 6.4

---

[6] It is recognized that daily milk production will vary through the lactation cycle. However, for the purpose of this analysis, an average daily production value is used.

[7] This ration is an "average" daily ration for this lactation period. In reality, producers would adjust the cow's ration over the lactation period to reflect increasing and then decreasing milk production per day. Also, the ration would likely include small amounts of salt and other minerals, which are not considered in this analysis.

provides the annual feed cost per cow, based on this analysis. Table 6.5 provides the budget per cow and the total enterprise for the "average" representative dairy farm.

TABLE 6.1 ALTERNATIVE FEEDS AND NUTRIENT CONTENT PER KILOGRAM OF FEED: (100% DRY MATTER BASIS)

Nutrients Consideration	Alfalfa(Hay)	Barley	Oats	Canola Meal	Silage
Energy (NE_L)mcal/Kg.	1.46	2.14	1.9	1.83	1.21
Crude Protein (CP) Kg.	0.194	0.13	0.132	0.369	0.178
Calcium (Ca) Kg.	0.0125	0.0009	0.0011	0.0064	0.0161
Phosphrous (P) Kg.	0.0023	0.0047	0.0039	0.0104	0.0038
Crude Fibre (CF) Kg.	0.285	0.056	0.12	0.146	0.304
Cost ($/Kg.)	0.101	0.155	0.168	0.215	0.103

Source: National Research Council. Requirements of Dairy Cattle, (1978). Washington, D. C.

TABLE 6.2 NUTRIENT REQUIREMENTS FOR 28.3KG. OF MILK OUTPUT PER COW PER DAY

minimum requirements	
Energy (NE_L)mcal/Kg.	30.427
Crude Protein (CP) Kg.	2.870
Calcium (Ca) Kg.	0.0966
Phosphrous (P) Kg.	0.0718
Crude Fibre (CF) Kg.	1.022
maximum requirements	
Total Dry Matter (DM) Kg.	20.8

Source: National Research Council. Requirements of Dairy Cattle, (1978). Washington, D. C.

TABLE 6.3 AVERAGE DAILY RATION PER COW (NO BST)

Ration Ingredients	Daily Ration Amount (Kg.)
Alfalfa hay	3.03
Barley	8.35
Oats	0.00
Canola meal	0.00
Silage	6.73
Dry Matter	18.10
Cost of daily ration per cow ($)	**2.29**

TABLE 6.4 FEEDING BUDGET PER DAIRY COW (NO BST)

Feed	Kg./day	Number of days	Cost/Kg. ($)	Total cost ($)
Alfalfa (Hay)	3.03	300	0.101	91.81
Barley	8.35	300	0.155	388.28
Silage	6.73	300	0.103	207.96
Total feed cost				688.04

TABLE 6.5 DAIRY ENTERPRISE BUDGET FOR THE REPRESENTATIVE FARM (NO BST)

(Annual milk output per cow is 8492.05 liters ~8492.05 Kg.)

	Per cow	Farm total
Revenue:		
Milk Sales	4452.55	316131.1
Milk Subsidy	142.17	10094.07
Milk Levies	(-)36.83	(-)2614.93
Miscellaneous Receipts	2.97	210.87
Gross Income	4597.69	326435.97
Operating Costs:		
Feed Cost	688.04	48850.91
Veterinary and Medicine	104.34	7408.14
Breeding	56.19	3989.49
Bedding and Supplies	148.31	10530.01
Milk Hauling	151.75	10774.25
Producer's Fees	85.64	6080.44
Utilities	97.56	6926.76
Fuel, Oil and Lube	55.7	3954.7
Building and Machine repairs	179.57	12749.47
Taxes and Insurance	56.78	4031.38
Miscellaneous	126.92	9011.32
Hired Labor	263.19	18686.49
Family Labor	539.58	38310.18
Total Operational Costs	2553.57	181303.5
Fixed Costs		
Rent	41.56	2950.76
Depreciation	347.87	24698.77
Interest	189.25	13436.75
Total Capital Cost	578.68	41086.28
Total Production Cost	3132.25	222389.8
NET RETURNS	1465.44	104046.17

6.4 IMPACTS OF BST

Research trials have suggested a milk production response to BST supplementation of between 20% (Kennelly et al., 1986) and 40% (Bauman et al., 1985). For the purpose of this analysis, it is assumed that the milk production response to BST adoption is 15%. This assumption is based on observations of dairy cows of different breeds, genetic potential, parity and geographical locations (under BST treatment) from which is concluded that the increase in average daily milk yield within commercial dairy herds is expected to be approximately 10-15% (Kennelly, 1994).

The cost of BST is assumed to be \$0.38 per dose per cow per day which is based on the BST price in the US (i.e., approximately \$0.25 US per dose per cow per day). The conversion is based on the assumption that the exchange rate is approximately \$0.65 (US) to \$1.00 (Canadian). It is therefore calculated that if BST is used for 300 days, the cost of BST will be \$114.00 per cow per year.

BST use has an impact on feed cost, as the cows require more nutrients for milk production under BST treatment (as discussed in Section 2). As such, the farmer requires more of these nutrients to meet the demand. Using the LP least cost model, the change in ration based on the assumed 15% increase in milk production and the cost is determined. The nutrient requirements for this scenario are shown in Table 6.6. and the resulting daily ration is provided in Table 6.7.

TABLE 6.6 NUTRIENT REQUIREMENTS FOR 32.54KG. OF MILK OUTPUT PER COW PER DAY WITH BST.

minimum requirements	
Energy (NE_L)mcal/Kg.	33.36
Crude Protein (CP) Kg.	3.185
Calcium (Ca) Kg.	0.108
Phosphrous (P) Kg.	0.0798
Crude Fibre (CF) Kg.	1.203
maximum requirements	
Total Dry Matter (DM) Kg.	20.8

Source: National Research Council. Requirements of Dairy Cattle, (1978). Washington, D. C.

TABLE 6.7 AVERAGE DAILY RATION PER COW (WITH BST)

Ration ingredients	Daily Ration Amount (Kg.)
Alfalfa hay	2.98
Barley	8.99
Oats	0.00
Canola meal	0.00
Silage	8.08
Dry Matter	20.05
Cost of daily ration per cow ($)	**2.52**

With the adoption of BST to produce 32.55Kg. of milk per cow per day (i.e., a 15% increase), it was determined that the least cost ration would consist of 2.98Kg. of Alfalfa (hay), 8.99Kg. of Barley, and 8.08Kg. of Silage daily (Table 6.7). The cost of this ration is $2.52. The adoption of BST to increase the milk output by 15% will require approximately 10% increase in feed cost based on the calculation. Without the use of BST, it was determined that the feed cost per cow was $688.00 for the lactation period. With the adoption of BST, the feed cost increases to $758. Total feed cost per cow, assuming adoption of BST, is shown in Table 6.8.

TABLE 6.8 FEEDING BUDGET PER DAIRY COW (WITH BST)

Feed	Kg./day	Number of days	Cost/Kg. ($)	Total cost ($)
Alfalfa (Hay)	2.98	300	0.101	90.29
Barley	8.99	300	0.155	418.04
Silage	8.08	300	0.103	249.67
Total feed cost				758.00

It is assumed that the adoption of BST will have impacts on other costs of production including veterinary and medicine, and hired and family labor. The calculation is based on the cost of activities provided by Appleby (1996), which indicates the cost of each activity per cow and also per hectoliter of milk sold. With this, the approximate percentage increase in cost for each activity can be estimated based on the expected increase in milk production. It was estimated that veterinary and medicine costs will increase by approximately 12%. Hired labor and family labor is also assumed to increase by 12.2% in each case based on similar calculations.

6.5 BST ADOPTION SCENARIOS

The two scenarios that will be considered in the adoption of BST are:

a) maintaining the current total milk level by reducing the herd size; and

b) producing more milk with quota expansion (maintaining herd size and purchasing extra quota).

These scenarios are chosen because Alberta producers have marketing quota within which they have to operate and manage their dairy enterprises. There is an investment cost for any extra quota required which was $205.05 per litre (Appleby, 1996) in 1996 and is currently over $500.00. For both scenarios, it is assumed that BST is used on all cows in the herd.

6.5.1 HERD SIZE REDUCTION SCENARIO

Given a 15% response to BST, if the producer wants to maintain his present milk quota and revenue and adopt BST, then the producer will have to reduce the number of cows. The total present milk sales from the 71 cows is $316,131.10 without BST. In this analysis, assuming that always 2.42% of the total milk output is used as feed to livestock and/or sold into the Optional Export Program (OEP), then the 97.58% should be equal to the available milk for sale (quota milk, over quota milk and other milk sales). For the producer to maintain his present revenue from milk sales ($316,131.10) at the current price of $52.52 per hectolitre, it means he has to produce 6019.25 hl of milk which constitutes 97.58% of the total milk produced. Hence the milk production should be 6168.53 hl, of which 149.28 hectolitres (2.42%) are used as feed to livestock and/or sold

into the OEP. Without BST, the average cow produces 84.92 hl of milk per year. With the use of BST, the cow will produce 97.66 hl per cow per year. With this level of production, the number of cows required to produce 6168.53 hl of milk will be 63.16 $\simeq$ 63 cows. Hence, approximately 8 cows must be culled in order to maintain the current quota level. This reduction will bring some changes in revenues and costs which will be described later in the section.

6.5.2 QUOTA EXPANSION SCENARIO

Alternatively, the farmer can choose to maintain the current herd size and purchase extra quota for the 15% increase in milk production resulting from adoption of BST. In this scenario, all 71 cows will be treated with BST. This will increase the total milk production by 15% which will require extra quota.

The milk quota level for the case is 4068.93 hectoliters. With the adoption of BST, the producer can produce 6927.364 hectoliters, assuming the current herd size is maintained. Based on the assumption that 2.26% (156.56 hl), 0.26% (17.32 hl) and 0.16% (11.08) of the total milk output are respectively used as feed to livestock, other milk sales and Optional Export Program (OEP) which sum up to 184.96 hl, the quantity of milk for sales will be 6742.40 hl which is far more than the quota level. For the total milk to be sold, the producer should purchase extra quota in the amount of 2673.47 hl. This implies that he will have to buy quota for 8.9116 hl or 891.16 liters of daily milk supply. At a quota price of $205.05[8] per liter, it means the producer should buy quota costing

---

[8] The quota price and the data for the analysis are taken from the Economics of Alberta Milk Production (Appleby, 1996). However, the current (1999) quota price is much higher.

$183,472.02. The annual "cost" for this additional quota, assuming a 6.06%[9] discount rate will be $11118.40, which can be considered as the investment cost.

6.6 BST IMPACTS AND PARTIAL BUDGETS

The partial budgets for the herd reduction and quota expansion scenarios are provided in Tables 6.9 and 6.10, respectively. These budgets are calculated based on assumptions and data discussed earlier in this section.

TABLE 6.9 PARTIAL BUDGET ASSUMING ADOPTION OF BST AND REDUCTION OF HERD SIZE TO MAINTAIN CURRENT REVENUE FROM MILK SALES (63 COWS)

Added Revenue		Reduced Revenue	
Miscellaneous	29.29	Nil	
Reduced Costs		Added Costs	
Feed	1096.91	BST	7182
Vet. And Medicine	23.36		
Hired Labor	74.40		
Family labor	125.38		
Investment on cows	301.13		
Advantage	**1650.47**	**Disadvantage**	**7182**

Change in net returns = **$1650.47- $7182= -$5531.53**

This analysis shows that the producers will be at a disadvantage of incurring more cost of $5531.53 by reducing their herd size and adopting the BST just to maintain their current milk sales revenue of $316,131.10. This may adversely affect net returns.

---

[9] Sources: Statistics Canada, CANSIM, Prime business loan rate; Bank of Canada, Bank of Canada

Although there are no significant changes in the variable costs and revenue, the cost of BST contributed to the disadvantage. Although there are reduced costs in terms of feed, veterinary and medicine, hired and family labour, and cow investment[10], this is less than the cost added from the BST adoption. The results indicate that BST adoption can be costly if milk supply is limited through quota.

TABLE 6.10 PARTIAL BUDGET ASSUMING ADOPTION OF BST (EXPANSION OF QUOTA)

Added Revenue		Reduced Revenue	
Milk Sales	47153.31	Nil	
Miscellaneous	35.92		
Total added Revenue	47188.13		
Reduced Costs		Added Costs	
Nil		BST	8094.00
		Feed	4984.20
		Vet. And Medicine	444.46
		Milk Hauling	1615.96
		Producer's Fees	912.35
		Hired Labor	1121.09
		Family labor	2298.27
		Investment (Quota)	11118.40
		Milk Levies	385.90
Advantage	**$47188.13**	**Disadvantage**	**$23745.83**

Change in net returns = **47188.13-23745.83= $23442.3**

Review, Ottawa. 1996.

[10] The reduced cost of investment is calculated based on the values of the culled cows and an appropriate opportunity cost of capital (i.e., the prime business loan rate of 6.06%) in 1996.

With the adoption of BST on all the 71 cows and expanding the quota, an increase of net returns by $23,442.3 was obtained. However, this result depends on factors such as the quota value and the magnitude of the BST response.

6.7 BREAK EVEN ANALYSIS

Break even analysis is very useful in analyzing the profitability of adopting BST. This provides the opportunity to determine "critical" values of relevant parameters related to the decision as to whether or not to adopt BST.

For the herd reduction scenario, the break-even cost of BST is $1650.47. This implies that the annual cost of BST per cow for the lactation cycle would be $26.20 instead of $114, or $0.09 per cow per day instead of $0.38. In contrast, the break-even cost of BST for the quota expansion scenario is $31536.30. This implies an annual cost of BST per cow for the lactation cycle of $444.17 instead of $114, or $1.48 per cow per day instead of $0.38. This would suggest that the general results for this scenario are "stable" over wide range of BST costs.

Under the herd size reduction scenario, at the current price of $52.52 per 1 hectoliter of milk, the break-even milk yield per cow per year should be such that the total of added revenue is $7182. This implies that the current added revenue should increase by $5531.53.or $87.80 per cow. A milk output of 97.66 hl per cow at $52.52 per hl amounts to a revenue of $5129.10 per cow. This amount ($5129.10 per cow) plus $87.80 would be equal to $5216.90. This implies that at a current price of milk, the maximum milk output required for the producer to "break-even" is 99.33 hl which is approximately a 16.97% increase over the scenario without BST. In other words, a BST

response of 16.97% is required instead of 15%. Alternatively, if the milk increase is 15%, then for the producer to obtain $5216.90 to enable him to have no net change for the BST technology (i.e., break-even price), the milk price would have to be increased to $53.42 from $52.52.

Under the quota expansion scenario at the current price of $52.52 per 1 hectoliter of milk, the minimum milk yield per cow per year that will bring no advantage or disadvantage to the producer should be such that the total of added revenue is $23,745.83. This implies that the current added revenue should reduce by $23,442.3 or $330.17 per cow. Milk output of 97.66 hl per cow at $52.52 per hl, amounts to a revenue of $5129.10 per cow. This amount ($5129.10 per cow) less $330.17 will be equal to $4798.93. This implies that at the current milk price, the milk output required for the producer to break-even is 91.37 hl which is approximately a 7.6% increase over the scenario without BST. In other words, a BST response of 7.6% is required instead of 15%. If the milk increase is 15%, then for the producer to obtain $4798.93 to enable him to have no net change in the BST technology, the break-even milk price is $49.14.

With the adoption of BST, and assuming a 15% response, the quota investment requirement could increase to $34560.70 annually. This corresponds to a break-even total quota investment of $570,308.58. This total quota investment cost is for 891.16 litres of milk per day as discussed earlier in this section. It follows therefore that the break-even price of the quota is approximately $640.00. Beyond this price, there will be a disadvantage to the producer for adopting the BST technology and expanding the quota levels.

6.8 CONCLUDING COMMENTS

The analysis shows that dairy producers are likely to make gains in the adoption of BST technology. However, the margin of the gains will depend on several factors including milk prices, BST cost, and quota price. Moreover, this analysis is based on an average dairy farm size of 71 cows. The analysis involved only the BST impacts on milk production and feed consumption by the animals. The analysis does not consider many potential changes which might occur in other farm enterprises which will ultimately affect revenues and costs (e.g., changes in feed, cropping, labor requirements and herd structure). Partial budgeting is usually not suitable for preparing a plan for the whole farm. This is because several enterprises might be involved in a change which cannot be easily considered in the partial budget.

SECTION 7 - THE SECTOR LEVEL IMPACT OF BST

7.1 INTRODUCTION

The purpose of this section is to identify a framework that can be used to assess the potential impact of BST on the Alberta dairy industry. The effects of this technology on quota values, number of farms and structure, cow numbers, and milk prices may be analyzed based on impacts at the farm level. Thus, the types of results generated by the modeling procedure, outlined earlier, are used as a starting point.

7.2 REGIONAL DIFFERENCES IN THE ALBERTA DAIRY INDUSTRY

The assessment of the sector-level impacts of BST in Alberta dairy industry is crucial to market development. This is because the development of Alberta's dairy industry depends on the market opportunities for the products from this sector. As significant adoption of BST may potentially be associated with incentives for increased milk supply, quota values, etc., it is imperative to assess the impact of BST at the sector level. Without assessment of the sector-level impacts of BST in the dairy sector, it will be difficult to predict how the BST will impact on the dairy market.

The objective of producers at the farm-level is to maximize returns on dairy production using BST technology subject to quota and resource constraints. Because the structure and size of dairy farms varies widely from region to region, Alberta is divided into five dairy producing regions. These regions include Southern Alberta (i.e., Medicine Hat and Letbridge areas), Calgary, Red Deer, Edmonton and Northern Alberta (i.e., Grand Prairie and Fort McMurray areas). For the assessment of the

sector-level impact of BST for Alberta dairy sector, representative dairy farms from each region would be identified and modeled based on herd size, using the framework discussed in Section 5. Given the differences between the various regions in Alberta, impacts will likely not be neutral as the distribution of dairy cows in terms of milk output is not uniform across the province (e.g., Table 7.1).

TABLE 7.1 PERCENTAGE DISTRIBUTION OF DAIRY COWS BY REGION IN ALBERTA, 1987

	Dairy Cow Category		
Region[a]	No[b]	Low[c]	High[d]
Southern Alberta	34	44	22
Calgary	48	36	16
Red Deer	49	37	14
Edmonton	62	25	13
Northern Alberta	50	50	0
Average	51	34	15

Source: Nicol, 1989

[a] Dairy producing regions as defined in the text.

[b] No milk output (e.g., heifers, cows in their dry period)

[c] Low milk output (e.g., based on genetic composition, age, etc.)

[d] High milk output (e.g., genetically superior dairy cows)

The impact of BST at the farm level of the representative farm for each region can be used to make inferences concerning the general impact of BST adoption in the Alberta dairy sector. With reference to the results from the framework discussed in Section 5, it can be deduced that the BST will have impact s on the Alberta dairy industry depending on how widely the drug is adopted by the dairy producers. This is because the performance of the individual dairy farmers in the sector will ultimately affect the general performance of the sector. The farm level analysis results would show the impact of BST on the herd size and farm structure

for the representative farms. At the sector level however, depending on the rate of BST adoption, milk prices and quota values may also be affected. The discussion below provides an indication of what could be said about sector level effects of BST based on the results at the farm level.

7.3 MODEL RESULTS

The framework model of the farm level adoption of BST, described in Section 5, would produce results which can be used to analyze the sector level impact of BST adoption in Alberta dairy industry. From the solution, the number of cows required to maximize returns based on the available resources and other constraints like the quota level can be identified. The excess cows that need to be culled to maximize returns will also be identified. However, the solution will indicate if the cows are the limiting (binding) factor to achieving even better results if there are not enough on the farm. This solution also provides information that can be used to determine the range of prices within which farmers will be likely to buy or sell cows.

The crops required to obtain the necessary nutrients needed by the cows to maximize output can be identified in the results. In addition, the quantity of each crop needed can be identified from the solution. The nutrient requirements to maximize returns can be found in the solution and the implicit value of each nutrient will be indicated in the form of shadow prices. The shadow prices of the quota can be used to identify the implicit value of any extra quota and the cost range within which the farmers would be willing to pay to achieve their objectives. The implicit values are used to

determine how the returns will be affected when there is a unit change of a particular resource or how much a farmer can afford to obtain that particular resources.

7.4 NUMBER OF COWS

The information generated from the solution can be used to identify the number of cows that will be needed to produce the current optimum results, assuming adoption of BST. This information can be used to infer how many cows will have to be culled, maintained or increased under the BST adoption. The knowledge of this can be used to assess the sector level impact of BST on the cow numbers depending on the region, herd size and quota levels. This information can be used as a clue to know which farms, depending on region, herd size and quota levels, will have to cull, maintain or increase cow numbers in order to stay competitive or stay in production. In general, the results can be used to identify the average number of cows that are likely to be used in each of the five regions.

7.5 FARM NUMBERS AND STRUCTURE

The farm numbers and structure will be affected by the adoption of BST. From the answer report, the resources that are required for optimum result under the adoption of BST will be identified which will include the herd size to be maintained, crops that are necessary for the farm production objective (as feeds and for sales) and labor requirements. The results at the farm level can be used to determine the farm structure that are likely to persist in which region, under what quota level and what herd size. In

addition to this, the number of farms that are required to meet al.berta's milk supply based on the quota regulations can be estimated.

7.6 MILK PRICES

Although the solution will not be able to indicate much about milk prices, it can be assumed that depending on the cost of production and the rate of adoption, milk prices will be affected. If the cost of milk production goes down at the farm level and the rate of BST adoption is significant, in other words, more farms adopt BST and assuming that milk consumption rate does not change, milk prices are likely to fall. In other words, milk prices might decrease if aggregate cost of production decreases. This is due to the feedback effect of production costs in the milk pricing formula. However, if the cost of milk production under BST increases, then milk price may not be likely to fall.

7.7 QUOTA VALUE

The shadow price of the quota from the solution will be the implicit value of the quota. In other words, the cost of any extra quota that the farmer may like to purchase to allow extra milk production. This results will be helpful to policy makers to identify the types of farms (i.e., by region or herd size) which are likely to bid up the price of quota. It can also be used to determine the direction of "flow" of any quota transfer attributable to BST.

SECTION 8 - CONCLUDING COMMENTS

A model framework was formulated in the paper that could be used to assess the impact of BST in the Alberta dairy sector. It provided a review of BST in terms of the effects on dairy cows, milk production, feed requirements, health and longevity, and reproductive capacity. It also made mention of possible farm-level adoption scenarios. The paper provided a review of the economic literature related to BST, highlighted some of the studies done on BST and the methodology used and results obtained from the studies.

The paper also identified and discussed an appropriate theoretical model that can be used to explain the economics of BST adoption. An appropriate farm-level empirical model was identified and discussed. An initial empirical analysis of BST adoption for a representative farm, using partial budgeting and break even analysis, was identified and discussed. Finally, a sector-level model capable of assessing the effects of BST on quota values, milk prices as well as the future structure of the dairy industry in Alberta was discussed, based on the farm-level analysis.

The empirical results from the partial budgeting show that, if the producer adopts BST and still wants to maintain current production and revenue levels, the producer will be disadvantaged due to the cost of the BST. Also, if the producer adopts BST on all the cows with the possibility of quota expansion, the price of BST could increase by approximately 400% from the estimated value before the producer would be indifferent to adoption of BST. Any increase in BST cost less than 400% makes BST adoption advantageous.

With respect to the quota level, the producer will be better off adopting BST, at the current quota price of $205.05 per litre. However, the producer will be worse off adopting BST if the quota price increases by more than 300% above 1996 levels (current quota value in 1999 is approximately $500 which is approximately a 244% increase). Any increase of quota price less than 300% makes BST adoption advantageous.

A change in technology is usually associated with a change in production which might result in increase in net returns. It might however be disadvantaged if a change in technology is not associated with a change in net returns due to the producer's choice (as in the first scenario). BST may have the potential of increasing milk producer's net returns but this will depend on factors like herd size, region of location, quota level, quota value, milk prices, BST cost and the costs of other inputs.

The questions that need to be addressed to enable this framework to be carried out is the cost of BST and the exact response to milk production. In addition, the exact cost of other inputs (e.g., feed, veterinary and medicine, etc.) associated with the adoption of BST should be clear. There should also be a better information on adoption rate. If all these questions are answered, the framework formulated in the paper would be able to help determine the impact of BST adoption in Alberta dairy industry to a high degree of accuracy.

REFERENCES

Adashi, E.Y., C.E. Resnick, M.E. Svoboda, and J.J.Van Wyk, (1986). Somatomedin-C as an Amplifier of Follicle Stimulating Hormone Action: Enhanced Accumulation of Adenosine3', 5'- Monophosphate. *Endocrinology Review* 118:149.

Adashi, E.Y., C.E. Resnick, R.G. Rossenfeld, (1989). Insulin-Like Growth Factor-1(IGF-1) and (IGF-II) Hormonal Action in Cultured Rat Granulosa Cells: Mediation Via type I not type II IGF Receptors. *Endocrinology Review* 126:216.

Appleby, T., (1996). Economics of Milk Production in Alberta. Economic Research and Logistic Branch, Alberta Agricultural, Food & Rural Development. Alberta.

Asimov, G.J. and N.K. Krouze, (1937). The Lactogenic reparations From the Anterior Pituitary and the Increase of Milk Yield in Cows. *Journal of Dairy Science* 20:289-306.

Baile, C.A., F.C. Buonomo, and G.G. Krivi, (1987). Future Development in BST Technology: National Invitational Workshop on Bovine Somatotropin. Extension service.- United States. Department of Agriculture, Cornell University, New York, US.

Bauman, D.E., M.J. DeGreeter, C.J. Peel, G.M. Lange, R.C. Gorewit, and R.W. Hammond (1982). Effect of Recombinantly Derived Bovine Growth Hormone (bGH) on Lactational Performance of High Yielding Dairy Cows. *Journal of Dairy Science* 65 (Suppl. 1): 121.

Bauman, D.E., P.J Eppard, M.J. DeGreeter and G.M. Lanza. (1985). Response of High Producing Dairy Cows to Long Term Treatment with Pituitary and Recombinant-Somatotropin. *Journal of Dairy Science*. 68: 1352-1362.

Bauman, D.E., (1989). Biology of Bovine Somatotropin in Dairy Cattle: Advanced Technologies Facing the Dairy Industry. bST, Cornell Cooperative Extension Animal Science Mimeograph Series #133 (Ithaca, NY: Cornell University, 1989), pp. 1-8.

Boehlje, M. D., V. R. Eidman, (1984). *Farm Management*. (New York. Wiley 1984)

Burton, J. H., B. W. Mcbride, K. Bateman, G. K. McLeod, R. K. Eggert, (1987). Recombinant Bovine Somatotropin: Effects on Production and Reproduction in Lactating Cows. *Journal of Dairy Science*. 70, Supplement :123

Butler, W.R. and R.D. Smith, (1989). Interrelationships Between Energy Balance and Postpartum Reproductive Faction in Dairy Cattle. *Journal of Dairy Science* 72:767-783.

Chalupa, W. and D.T. Galligan, (1989). Nutritional Implications of Somatotropin for Lactating Cows. *Journal of Dairy Science* 72:2510-2524.

Chilliard, Y., (1989). Long-Term Effects of recombinant Bovine Somatotropin (rbST) on Dairy Cow Performances: A Review. Use of Somatotropin in Livestock Production, K. Sejrsen, M. Vestergaard, and A. Neimann-Sorensen (eds.) (New York, NY: Elsevier Applied Science).

Chirgwin, T. M., A.E. Pryzybyla, R.J. Macdonald, and W.J. Rutter, (1979). Isolation of Biologically Active Ribonucleic Acid from Sources Enriched in Robonuclease. Biochem. 18:5294.

De Boer, G., Kennelly, J. Shelford, J. Peterson, R. and Holbek, N. (1988). Efficacy and Safety of Recombinantly Derived Bovine Somatotropin for Dairy Cows. *Canada Journal of Animal Science.*

D'Ercole, A.J., A.D. Stiles, and L.E. Underwood (1984). Tissue concentrations of somatomedin C: further evidence for multiple sites of synthesis and paracrine or autocrine mechanism of action. *National Academy of Science.* 81:935.

Doll, J. P., F. Orazem, (1984). *Production Economics: Theory with Application.* Grid Inc., Columus, Ohio.

Fallert, R. (1987). BST and The Dairy Industry: A National, Regional, and Farm-Level Analysis. USDA Agricultural Report 579.

Ferguson, James D., (1990). Bovine Somatotropin Reproduction and Health: NIH Technology Assessment Conference Abstracts (Bethesda, MD: National Institutes of Health, 1990), pp. 65-81.

Ferguson, J. D. and A. Skidmore, (1989). Bovine Somatotropin-Reproduction and Health: Advanced Technologies Facing the Dairy Industry: bST, Cornell Cooperative Extension. Animal Science Mimeograph Series #133 (Ithaca, NY: Cornell University, 1989).

Glim, D.R., V.E. Baracos, and J. Kennelly, (1988). Effect of BST on the Distribution of Immunoreactive Insulin-Like Growth Factor-1 in Lactating Bovine Mammary Tissue. *Journal of Dairy Science* 71:2923.

Hard, D.L. (1988). Effect of Long Term Sometribove, USAN (Recombinant Methionyl Bovine Somatotropin), Treatment in a Prolonged Release System on Milk Yield, Animal Health and Reproductive Performance-Pooled Across Four Sites. *Journal of Dairy Science* :210.

Helming, J., J. Hammond, (1991). Potential Impact of BST on the Minnesota Milk Supply. Department of Agricultural and Applied Economics, University of Minnesota. St. Paul, MN.

Isaksson, O.G.P., S. Eden, and , J.O. Jansson, (1985). Mode of Action of Pituitary Growth Hormone on Target Cells. *Annual Review of Physiology*. 47:483.

Jeffrey, S. R., V. R. Eidman, (1994). Organizational Adjustments for Upper Midwestern Dairy Farmers. *Journal of American Society of Farm Managers and Rural Appraisers* Volume 57-58.

Johnsson, I.D. and I.C. Hart, (1986). *Manipulation of Milk Yield with Growth Hormone, Recent Advances in Animal Nutrition.* W. Haresign and D.J.A. Cole (eds.), Butterworths, London, pp. 105-123.

Kennelly, J., V. Adamaowicz, G. DeBoor, N. French, D. Gibson, M. Hancock, B. Kirkpatrick, G. Matheson, L. Milligan, F. Novak, and M. Song, (1986). Dairy Cattle Research at the University of Alberta Proceedings of the Alberta Dairy Seminar: Back to Basics. pp 30-36.

Kennelly, J., (1994). Influence of Bovine Somatotropin Injection on Nutritional Requirements, Metabolic Responses, milk Production, Quality, and Reproduction in Dairy Cows. Department of Animal Science. University of Alberta, Edmonton, Alberta.

Nicol, K., (1989). Potential dairy sector adjustments to the widespread adoption of Bovine Growth Hormone. University of Lethbridge, Lethbridge, Alberta.

Noakes, D.E., (1991). Use of Somatotropin in the Dairy Cow with Regard to Cow Safety. *Journal of Dairy Science*

National Research Council. National Academy of Sciences. Nutrients Requirements of Dairy Cattle, (1978). Washington, D. C.

Oxley, J., G. Fox, G. Moschini, (1989). The Potential Economic Impact of Bovine Somatotropin on the Ontario Dairy Industry. Department of Agricultural Economics and Business, University of Guelph, Ontario. Working Paper WP89/6.

Peel, C.J. and D.E. Bauman, (1987). Somatotropin and Lactation. *Journal of Dairy Science* 70:474.

Phipps, R.H., (1989). A Review of the Influence of Somatotropin on Health, Reproduction and Welfare in Lactating Dairy Cows: Use of Somatotropin in Livestock Production. K. Sejrsen, M. Vestergaard and A. Neimann-Sorensen (eds.) (New York, NY: Elsevier Applied Science, 1989).

Soderholm, C. G., D.E. Ollerby, J. C. Linn, F. P. Ehle, J. E. Wheaton, W. P. Hanson, and R. J. Annestad, (1988). Effects of Recombinant Bovine Somatotropin on Milk Production, Body composition and Physiological Parameters. *Journal of Dairy Science* 71:355

Stennes, B. K., R. R. Barichello, J. D. Graham, (1990). Bovine Somatotropin and the Canadian Dairy Industry: An economic analysis. Department of Agricultural Economics, University of British Columbia. (Working Paper 1/91)

Trelawny, P. (1986). A Preliminary Assessment of the Short –Term Economic Effects of Bovine Somatotropin." Inputs and Technology Division, Policy Branch, Agricultural Canada. Ottawa.

APPENDIX

APPENDIX A	MATRIX PRESENTATION FOR A LINEAR PROGRAMMING MODEL						
	ASSUMING NO BST		ADOPTION IN A DAIRY FIRM.				
Resources			Activities				
	wheat(bu)	barley(bu)	flax(bu)	oats	canola(bu)	hay(bu)	alfalfa(bu)
Land (ha)	awj1	abj1	afj1	acj1	asj1	ahj1	apj1
wheat(ha)	awj1						
barley(ha)		abj1					
flax(ha)			afj1				
oats				acj1			
canola					asj1		
hay(ha)						ahj1	
alfalfa							apj1
LABOR(mhrs.)	atwj1	atbj1	atfj1	atcj1	atsj1	athj1	atpj1
Feb-Apr.	atwj1-1	atbj1-1	atfj1-1	atcj1-1	atsj1-1	athj1-1	atpj1-1
May-Jul.	atwj1-2	atbj1-2	atfj1-2	atcj1-2	atsj1-2	athj1-2	atpj1-2
Aug.-Oct.	atwj1-3	atbj1-3	atfj1-3	atcj1-3	atsj1-3	athj1-3	atpj1-3
Nov.-Jan.	atwj1-4	atbj1-4	atfj1-4	atcj14	atsj1-4	athj1-4	atpj1-4
FETILIZER							
Mineral(kg)	alwj1	albj1	alfj1	alcj1	alsj1	alhj1	alpj1
Organic(Kg)	algwj1	algbj1	algfj1	algcj1	algsj1	alghj1	algpj1
FEED							
Dry M.(lb)	(-)Vhwj1-1	(-)Vhbj1-1	(-)Vhfj1-1	(-)Vhcj1-1	(-)Vhsj1-1	(-)Vhhj1-1	(-)Vhpj1-1
Cr. Pro.(lb)	(-)Vhwj1-2	(-)Vhbj1-2	(-)Vhfj1-2	(-)Vhcj1-2	(-)Vhsj1-2	(-)Vhhj1-2	(-)Vhpj1-2
Cr. Fib.(lb)	(-)Vhwj1-3	(-)Vhbj1-3	(-)Vhfj1-3	(-)Vhcj1-3	(-)Vhsj1-3	(-)Vhhj1-3	(-)Vhpj1-3
Calcium(g)	(-)Vhwj1-4	(-)Vhbj1-4	(-)Vhfj1-4	(-)Vhcj1-4	(-)Vhsj1-4	(-)Vhhj1-4	(-)Vhpj1-4
Phos.(g)	(-)Vhwj1-5	(-)Vhbj1-5	(-)Vhfj1-5	(-)Vhcj1-5	(-)Vhsj1-5	(-)Vhhj1-5	(-)Vhpj1-5
Non-Prot.(g)	(-)Vhwj1-6	(-)Vhbj1-6	(-)Vhfj1-6	(-)Vhcj1-6	(-)Vhsj1-6	(-)Vhhj1-6	(-)Vhpj1-6
Cows							
Heifer							
PRODUCT							
Crop for sales							
wheat(bu)	Vpwj1						
barley(bu)		Vpbj1					
flax(bu)			Vpfj1				
oats(bu)				Vpcj1			
canola(bu)					Vpsj1		
hay(bu)						Vphj1	
Milk(Total)(T)							
beef(Tons.)							
Gr. Inc. ($)	Vswj1	Vsbj1	Vsfj1	Vscj1	Vssj1	Vshj1	Vspj1
Expen.($)	aswj1	asbj1	asfj1	ascj1	assj1	ashj1	aspj1
MAX Profit($)							

CONTINUATION (APPENDIX A)

	LABOR	Feb-Apr.	May-Jul.	Aug.-Oct.	Nov.-Jan.	FETILIZER	Mineral(kg)
Land (ha)							
wheat(ha)							
barley							
flax							
oats							
canola							
hay							
alfalfa							
LABOR	-1						
Feb-Apr.		-1					
May-Jul.			-1				
Aug.-Oct.				-1			
Nov.-Jan.					-1		
Mineral(kg)							-1
Organic(Kg)							
FEED							
Dry M.(lb)							
Cr. Pro.(lb)							
Cr. Fib.(lb)							
Calcium							
Phos.							
Non-Prot.							
Cows							
Heifer							
PRODUCT							
Crop for sa							
wheat(ha)							
barley							
flax							
oats(bu)							
canola							
hay							
Milk(Total)							
beef							
Gr. Inc. ($)							
Expen.($)							
MAX Profit($)							

CONTINUATION (APPENDIX A)

	Organic(Kg)	FEED	Dry M.(lb)	Cr. Pro.(lb)	Cr. Fib.(lb)	Calcium(g)	Phos.(g)
Land (ha)							
wheat(ha)							
barley							
flax							
oats							
canola							
hay							
alfalfa							
LABOR							
Feb-Apr.							
May-Jul.							
Aug.-Oct.							
Nov.-Jan.							
Mineral(kg)							
Organic(Kg)	-1						
FEED							
Dry M.(lb)			-1				
Cr. Pro.(lb)				-1			
Cr. Fib.(lb)					-1		
Calcium						-1	
Phos.							-1
Non-Prot.							
Cows							
Heifer							
PRODUCT							
Crop for sa							
wheat(ha)							
barley							
flax							
oats							
canola							
hay							
Milk(Total)							
beef							
Gr. Inc. ($)							
Expen.($)						ascj1	aspj1
MAX Profit($)							

CONTINUATION (APPENDIX A)

	Non-Prot.(g)	Cows(lp)	Cows(mp)	Cows(hp)	Heifer	PRODUCT	Crop for sa(bu)
Land (ha)							
wheat(ha)							
barley							
flax							
oats							
canola							
hay							
alfalfa							
LABOR							
Feb-Apr.							
May-Jul.							
Aug.-Oct.							
Nov.-Jan.							
Mineral(kg)							
Organic(Kg)							
FEED							
Dry M.(lb)		ahdmj2	ahdmj2	ahdmj2	ahdmj2		
Cr. Pro.(lb)		ahcpj2	ahcpj2	ahcpj2	ahcpj2		
Cr. Fib.(lb)		ahcfj2	ahcfj2	ahcfj2	ahcfj2		
Calcium		ahcj2	ahcj2	ahcj2	ahcj2		
Phos.		ahpj2	ahpj2	ahpj2	ahpj2		
Non-Prot.	-1	ahnpj2	ahnpj2	ahnpj2	ahnpj2		
Cows							
Heifer							
PRODUCT							
Crop for sa							
wheat(ha)							
barley							
flax							
oats							
canola							
hay							
Milk(Total)		Vpblpj2	Vpbmpj2	Vpbhpj2			
beef							
Gr. Inc. ($)		Vsmlj2	Vsmlj2	Vsmlj2			
Expen.($)	asnpj1	asblpj2	asbmpj2	asbhpj2			
MAX Profit($)							

CONTINUATION (APPENDIX A)

		(Tonnes)					
	Beef(tons.)	Milk(Total)	Gr. Inc. ($)	Expen.($)	MAX Profit($)		RHS
Land (ha)						(=<)	bi
wheat(ha)						(=<)	bw
barley						(=<)	bb
flax						(=<)	bf
oats						(=<)	bc
canola						(=<)	bs
hay						(=<)	bh
alfalfa						(=<)	bp
LABOR						(=<)	bt
Feb-Apr.						(=<)	bt-1
May-Jul.						(=<)	bt-2
Aug.-Oct.						(=<)	bt-3
Nov.-Jan.						(=<)	bt-4
Mineral(kg)						(=<)	bl
Organic(Kg)						(=<)	blo
FEED							
Dry M.(lb)						(=>)	bdm
Cr. Pro.(lb)						(=>)	bcp
Cr. Fib.(lb)						(=>)	bcf
Calcium						(=>)	bca
Phos.						(=>)	bph
Non-Prot.						(=>)	bnp
Cows	Vpbej2					(=<)	bco
Heifer						(=<)	bhe
PRODUCT							
Crop for sa							
wheat(ha)						(=>)	Qpw
barley						(=>)	Qpb
flax						(=>)	Qpf
oats						(=>)	Qpc
canola						(=>)	Qps
hay						(=>)	Qph
Milk(Total)		-1				(=<)	QpmT
beef	1					(=>)	Qpbe
Gr. Inc. ($)	Vsbej2		-1			(=)	0
Expen.($)	asbej2			-1		(=)	0
MAX Profit($)			1	-1	1	(=)	0

APPENDIX B	MATRIX PRESENTATION FOR A LINEAR PROGRAMMING MODEL						
	ASSUMING BST ADOPTION ON ALL THE DAIRY COWS						
Resources			Activities				
	wheat(bu)	barley(bu)	flax(bu)	oats	canola(bu)	hay(bu)	alfalfa(bu)
Land (ha)	awj1	abj1	afj1	acj1	asj1	ahj1	apj1
wheat(ha)	awj1						
barley(ha)		abj1					
flax(ha)			afj1				
oats				acj1			
canola					asj1		
hay(ha)						ahj1	
alfalfa							apj1
LABOR(mhrs.)	atwj1	atbj1	atfj1	atcj1	atsj1	athj1	atpj1
Feb-Apr.	atwj1-1	atbj1-1	atfj1-1	atcj1-1	atsj1-1	athj1-1	atpj1-1
May-Jul.	atwj1-2	atbj1-2	atfj1-2	atcj1-2	atsj1-2	athj1-2	atpj1-2
Aug.-Oct.	atwj1-3	atbj1-3	atfj1-3	atcj1-3	atsj1-3	athj1-3	atpj1-3
Nov.-Jan.	atwj1-4	atbj1-4	atfj1-4	atcj14	atsj1-4	athj1-4	atpj1-4
FETILIZER							
Mineral(kg)	alwj1	albj1	alfj1	alcj1	alsj1	alhj1	alpj1
Organic(Kg)	algwj1	algbj1	algfj1	algcj1	algsj1	alghj1	algpj1
FEED							
Dry M.(lb)	(-)Vhwj1-1	(-)Vhbj1-1	(-)Vhfj1-1	(-)Vhcj1-1	(-)Vhsj1-1	(-)Vhhj1-1	(-)Vhpj1-1
Cr. Pro.(lb)	(-)Vhwj1-2	(-)Vhbj1-2	(-)Vhfj1-2	(-)Vhcj1-2	(-)Vhsj1-2	(-)Vhhj1-2	(-)Vhpj1-2
Cr. Fib.(lb)	(-)Vhwj1-3	(-)Vhbj1-3	(-)Vhfj1-3	(-)Vhcj1-3	(-)Vhsj1-3	(-)Vhhj1-3	(-)Vhpj1-3
Calcium(g)	(-)Vhwj1-4	(-)Vhbj1-4	(-)Vhfj1-4	(-)Vhcj1-4	(-)Vhsj1-4	(-)Vhhj1-4	(-)Vhpj1-4
Phos.(g)	(-)Vhwj1-5	(-)Vhbj1-5	(-)Vhfj1-5	(-)Vhcj1-5	(-)Vhsj1-5	(-)Vhhj1-5	(-)Vhpj1-5
Non-Prot.(g)	(-)Vhwj1-6	(-)Vhbj1-6	(-)Vhfj1-6	(-)Vhcj1-6	(-)Vhsj1-6	(-)Vhhj1-6	(-)Vhpj1-6
BST (mg)							
Cows							
Heifer							
PRODUCT							
Crop for sa							
wheat(bu)	Vpwj1						
barley(bu)		Vpbj1					
flax(bu)			Vpfj1				
oats(bu)				Vpcj1			
canola(bu)					Vpsj1		
hay(bu)						Vphj1	
Milk (BST)(T)							
Milk(Total)(T)							
beef(Tons.)							
Gr. Inc. ($)	Vswj1	Vsbj1	Vsfj1	Vscj1	Vssj1	Vshj1	Vspj1
Expen.($)	aswj1	asbj1	asfj1	ascj1	assj1	ashj1	aspj1
MAX Profit($)							

CONTINUATION (APPENDIX B)

	mh						
	LABOR	Feb-Apr.	May-Jul.	Aug.-Oct.	Nov.-Jan.	FETILIZER	Mineral(kg)
Land (ha)							
wheat(ha)							
barley							
flax							
oats							
canola							
hay							
alfalfa							
LABOR	-1						
Feb-Apr.		-1					
May-Jul.			-1				
Aug.-Oct.				-1			
Nov.-Jan.					-1		
Mineral(kg)							-1
Organic(Kg)							
FEED							
Dry M.(lb)							
Cr. Pro.(lb)							
Cr. Fib.(lb)							
Calcium							
Phos.							
Non-Prot.							
BST (mg)							
Cows							
Heifer							
PRODUCT							
Crop for sa							
wheat(ha)							
barley							
flax							
oats(bu)							
canola							
hay							
Milk (BST)							
Milk(Total)							
beef							
Gr. Inc. ($)							
Expen.($)							
MAX Profit($)							

CONTINUATION (APPENDIX B)

	Organic(Kg)	FEED	Dry M.(lb)	Cr. Pro.(lb)	Cr. Fib.(lb)	Calcium(g)	Phos.(g)
Land (ha)							
wheat(ha)							
barley							
flax							
oats							
canola							
hay							
alfalfa							
LABOR							
Feb-Apr.							
May-Jul.							
Aug.-Oct.							
Nov.-Jan.							
Mineral(kg)							
Organic(Kg)	-1						
FEED							
Dry M.(lb)			-1				
Cr. Pro.(lb)				-1			
Cr. Fib.(lb)					-1		
Calcium						-1	
Phos.							-1
Non-Prot.							
BST (mg)							
Cows							
Heifer							
PRODUCT							
Crop for sa							
wheat(ha)							
barley							
flax							
oats							
canola							
hay							
Milk (BST)							
Milk(Total)							
beef							
Gr. Inc. ($)							
Expen.($)						ascj1	aspj1
MAX Profit($)							

CONTINUATION (APPENDIX B)

	Non-Prot.(g)	BST (mg)	Cows(lp)	Cows(mp)	Cows(hp)	Heifer	PRODUCT
Land (ha)							
wheat(ha)							
barley							
flax							
oats							
canola							
hay							
alfalfa							
LABOR							
Feb-Apr.							
May-Jul.							
Aug.-Oct.							
Nov.-Jan.							
Mineral(kg)							
Organic(Kg)							
FEED							
Dry M.(lb)			ahdmj2	ahdmj2	ahdmj2	ahdmj2	
Cr. Pro.(lb)			ahcpj2	ahcpj2	ahcpj2	ahcpj2	
Cr. Fib.(lb)			ahcfj2	ahcfj2	ahcfj2	ahcfj2	
Calcium			ahcj2	ahcj2	ahcj2	ahcj2	
Phos.			ahpj2	ahpj2	ahpj2	ahpj2	
Non-Prot.	-1		ahnpj2	ahnpj2	ahnpj2	ahnpj2	
BST (mg)			ablpj2	abmpj2	abhpj2		
Cows							
Heifer							
PRODUCT							
Crop for sa							
wheat(ha)							
barley							
flax							
oats							
canola							
hay							
Milk (BST)			Vpblpj2	Vpbmpj2	Vpbhpj2		
Milk(Total)			Vpblpj2	Vpbmpj2	Vpbhpj2		
beef							
Gr. Inc. ($)			Vsmlj2	Vsmlj2	Vsmlj2		
Expen.($)	asnpj1	asbt	asblpj2	asbmpj2	asbhpj2		
MAX Profit($)							

CONTINUATION (APPENDIX B)

			(kg)	(Tonnes)			
	Crop for sa	Beef(tons.)	Milk (BST)	Milk(Total)	Gr. Inc. ($)	Expen.($	MAX Profit($)
Land (ha)							
wheat(ha)							
barley							
flax							
oats							
canola							
hay							
alfalfa							
LABOR							
Feb-Apr.							
May-Jul.							
Aug.-Oct.							
Nov.-Jan.							
Mineral(kg)							
Organic(Kg)							
FEED							
Dry M.(lb)							
Cr. Pro.(lb)							
Cr. Fib.(lb)							
Calcium							
Phos.							
Non-Prot.							
BST (mg)							
Cows		Vpbej2					
Heifer							
PRODUCT							
Crop for sa							
wheat(ha)							
barley							
flax							
oats							
canola							
hay							
Milk (BST)			-1				
Milk(Total)							
beef		1					
Gr. Inc. ($)		Vsbej2			-1		
Expen.($)		asbej2				-1	
MAX Profit($)					1	-1	1

CONTINUATION (APPENDIX B)

		RHS
Land (ha)	(=<)	bi
wheat(ha)	(=<)	bw
barley	(=<)	bb
flax	(=<)	bf
oats	(=<)	bc
canola	(=<)	bs
hay	(=<)	bh
alfalfa	(=<)	bp
LABOR	(=<)	bt
Feb-Apr.	(=<)	bt-1
May-Jul.	(=<)	bt-2
Aug.-Oct.	(=<)	bt-3
Nov.-Jan.	(=<)	bt-4
Mineral(kg	(=<)	bl
Organic(K	(=<)	blo
FEED		
Dry M.(lb)	(=>)	bdm
Cr. Pro.(lb)	(=>)	bcp
Cr. Fib.(lb)	(=>)	bcf
Calcium	(=>)	bca
Phos.	(=>)	bph
Non-Prot.	(=>)	bnp
BST (mg)	(=<)	bbst
Cows	(=<)	bco
Heifer	(=<)	bhe
PRODUCT		
Crop for sa		
wheat(ha)	(=>)	Qpw
barley	(=>)	Qpb
flax	(=>)	Qpf
oats	(=>)	Qpc
canola	(=>)	Qps
hay	(=>)	Qph
Milk (BST)	(=>)	Qpbs
Milk(Total)	(=<)	QpmT
beef	(=>)	Qpbe
Gr. Inc. ($)	(=)	0
Expen.($)	(=)	0
MAX Profit	(=)	0

21386

THESIS 1999 21386
c. 2
ODUPONG, ERNEST (1999)
A MODEL FRAMEWORK FOR BST
IMPACT ASSESSMENT ON THE. . .

THESIS 1999 21386
c. 2
ODUPONG, ERNEST (1999)
A MODEL FRAMEWORK FOR BST
IMPACT ASSESSMENT ON THE. . .

E. R. BERG MEMORIAL LIBRARY
Department of Rural Economy
University of Alberta
Edmonton, Alberta T6G 2H1
Phone (403) 432-4225